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Chisholm, Henry,	1881
Clark, Henry G.,	1881
Clemes, J. P.,	1876
Daddow, S. H.,	1875
D'Aligny, H. F. Q.,	1875
Dresser, Charles A.,	1878
Firmstone, William,	1877
Fuller, John T.,	1880
Gould, Robert H.,	1878
Harris, Stephen,	1874
Healy, Maurice,	1881
Hunt, Thomas,	1872
Jenney, F. B.,	1876
Jernegan, J. L.,	1881
Lee, Washington,	1872
Liebenau, Charles von,	1875
Lord, John C.,	1872
Lorenz, W., Jr.,	1881
McIntire, Henry M.,	1880
Mickley, J. W.,	1880
Moore, Charles W.,	1877
Newton, Henry,	1877
Painter, Howard,	1876
Phelps, Walter,	1878
Pleasants, Henry,	1880
Richter, C. E.,	1877
Robinson, Thomas W.,	1880
Schirmer, J. F. L.,	1877
Steitz, Augustus,	1876
St. John, I. M.,	1880
Stoelting, Hermann,	1875
Walz, Isidor,	1877
Wendel, Dr. A.,	1881
Witherbee, J. G.,	1875
Worthington, Henry R.,	1880

RULES

ADOPTED MAY, 1873. AMENDED MAY, 1875, MAY, 1877, MAY, 1878, FEBRUARY, 1880, and FEBRUARY, 1881.

I.

OBJECTS.

The objects of the AMERICAN INSTITUTE OF MINING ENGINEERS are to promote the Arts and Sciences connected with the economical production of the useful minerals and metals, and the welfare of those employed in these industries, by means of meetings for social intercourse, and the reading and discussion of professional papers, and to circulate, by means of publications among its members and associates, the information thus obtained.

II.

MEMBERSHIP.

The Institute shall consist of Members, Honorary Members, and Associates. Members and Honorary Members shall be professional mining engineers, geologists, metallurgists, or chemists, or persons practically engaged in mining, metallurgy, or metallurgical engineering. Associates shall include all suitable persons desirous of being connected with the Institute and duly elected as hereinafter provided. Each person desirous of becoming a member or associate shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting upon receiving three-fourths of the votes cast, and shall become a member or associate on the payment of his first dues. Each person proposed as an honorary member shall be recommended by at least ten members or associates, approved by the Council and elected by ballot at a regular meeting on receiving nine-tenths of the votes cast; *Provided*, that the number of honorary members shall not exceed twenty. The Council may at any time change the classification of a person elected as associate, so as to make him a member, or *vice versâ*, subject to the approval of the Institute. All members and associates shall be equally entitled to the privileges of membership; *Provided*, that honorary members shall not be entitled to vote or to be members of the Council.

Any member or associate may be stricken from the list on recommendation of the Council, by the vote of three-fourths of the members and associates present at any annual meeting, due notice having been mailed in writing by the Secretary to the said member or associate.

III.

DUES.

The dues of members and associates shall be ten dollars per annum, payabl. in advance at the annual meeting; *Provided*, that persons elected at the meeting following the annual meeting shall pay eight dollars, and persons elected at the meeting preceding the annnal meeting shall pay four dollars as dues for the current year. Honorary members shall not be liable to dues. Any member or associate may become, by the payment of one hundred dollars at any one time, a life member or associate, and shall not be liable thereafter to annual dues. Any member or associate in arrears may at the discretion of the Council be deprived of the receipt of publications, or stricken from the list of members when in arrears for one year; *Provided*, that he may be restored to membership by the Council on payment of all arrears, or by re-election after an interval of three years.

IV.

OFFICERS.

The affairs of the Institute shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, a Secretary and a Treasurer, who shall be elected from among the members and associates of the Institute at the annual meetings, to hold office as follows:

The President, the Secretary, and the Treasurer for one year (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of these rules, for two consecutive years), the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. At each annual meeting a President, three Vice-Presidents, three Managers, a Secretary and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the Council or the Institute; and the Council may in its discretion require bonds to be given by the Treasurer. At each annual meeting the Council shall make a report of proceedings to the Institute together with a financial statement.

Vacancies in the Council may occur by death or resignation; or the Council may by vote of a majority of all its members declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the

Council meetings or perform the duties of his office. All vacancies shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; *Provided*, that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary, and recorded by him with the minutes.

V.

ELECTIONS.

The annual election shall be conducted as follows: Nominations may be sent in writing to the Secretary, accompanied with the names of the proposers, at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before the said meeting, mail to every member or associate (except honorary members), a list of all the nominations for each office so received, stamped with the seal of the Institute, together with a copy of this rule, and the names of the persons ineligible for election to each office. And each member or associate, qualified to vote, may vote, either by striking from or adding to the names of the said list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing said altered or prepared ballot with his name, and either mailing it to the Secretary, or presenting it in person at the annual meeting: *Provided*, that no member or associate, in arrears since the last annual meeting, shall be allowed to vote until the said arrears shall have been paid. The ballots shall be received and examined by three Scrutineers, appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices, shall be declared elected, and the Scrutineers shall so report to the presiding officer. The ballots shall be destroyed, and a list of the elected officers, certified by the Scrutineers, shall be preserved by the Secretary.

VI.

MEETINGS.

The annual meeting of the Institute shall take place on the third Tuesday of February, at which a report of the proceedings of the Institute, and an abstract of the accounts, shall be furnished by the Council. Two other regular meetings of the Institute, shall be held in each year, at such times and places as the Council shall select. Special meetings may be called whenever the Council sees fit; and the Secretary shall call a special meeting on a requisition signed by fifteen or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

Every question which shall come before any meeting of the Institute, shall be decided, unless otherwise provided by these Rules, by the votes of the majority of the members then present. The place of meeting shall be fixed in advance by the Institute, or, in default of such determination, by the Council, and notice of all meetings shall be given by mail, or otherwise, to all members and associates, at least twenty days in advance. Any member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

VII.

PAPERS.

The Council shall have power to decide on the propriety of communicating to the Institute any papers which may be received, and they shall be at liberty, when they think it desirable, to direct that any paper read before the Institute, shall be printed in the Transactions. Intimation, when practicable, shall be given at each General Meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting. The reading of papers shall not be delayed beyond such hour as the presiding officer shall think proper; and the election of members or other business may be adjourned by the presiding officer, to permit the reading and discussion of papers.

The copyright of all papers communicated to, and accepted by the Institute, shall be vested in it, unless otherwise agreed between the Council and the author. The author of each paper read before the Institute shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing, provided said copies are not intended for sale. The Institute is not, as a body, responsible for the statements of fact or opinion, advanced in papers or discussions, at its meetings, and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

VIII.

AMENDMENTS.

These Rules may be amended, at any annual meeting, by a two-thirds vote of the members present, provided that written notice of the proposed amendment shall have been given at a previous meeting.

PROCEEDINGS

OF THE

LAKE SUPERIOR MEETING.

AUGUST, 1880.

In accordance with a programme arranged by a committee of the Institute, consisting of Mr. William P. Shinn, of St. Louis, chairman, and Mr. Joseph D. Weeks, of Pittsburgh, secretary, the members of the Institute, with their ladies and invited guests, assembled in Chicago on Sunday morning, August 22d. A special train, provided by the Chicago and Northwestern Railway, left Chicago on Monday morning at 7.50 o'clock, and conveyed the party to Marquette, arriving at 9 o'clock P.M.

Here the steamer Northern Queen, which had been chartered by the committee for the accommodation of the Institute, was in waiting, and the members and ladies at once took up their quarters on the boat.

EXCURSIONS IN THE MARQUETTE IRON REGION.

Local Committee.

EXECUTIVE.—J. C. Morse, chairman; C. Y. Osburn, secretary; D. F. Wadsworth, treasurer; C. H. Hall, H. Merry.

RECEPTION.—S. P. Ely, J. P. Pendill, E. Breitung, W. F. Swift, A. P. Swineford, J. C. Fowle, C. G. Griffey.

TRANSPORTATION.—Samuel Schoch, D. Morgan, D. H. Merritt, J. Pickands.

FINANCE.—Peter White, A. W. Maitland, W D. Rees, E. R. Hall.

EXCURSIONS.—W. E. Dickinson, H. A. Burt, A. Kidder, C. E. Wright.

REFRESHMENTS.—J. Q. Adams, H. H. Stafford, Joseph Kirkpatrick, D. H. Bacon.

On Tuesday the iron mines in the vicinity of Negaunee and Ishpeming were visited, transportation being provided by special trains on the Marquette, Houghton and Ontonagon Railroad. In the morning the McComber, South Jackson, and Jackson mines were inspected, and in the afternoon the Cleveland, New York, Lake Superior, and Barnum mines. Dinner was provided at Negaunee, and gracefully served by the ladies of the town.

In the evening the first session of the Institute was held in the saloon of the steamer. The President, William P. Shinn, of St. Louis, congratulated the Institute on the happy consummation of the wishes of its members to have a meeting on Lake Superior. After tedious and baffling negotiations arrangements had been com-

pleted which afforded every prospect for a successful meeting. An address on the Progress of Metallurgical Industry in the United States since the Centennial Year, which he had in preparation but unfortunately had been prevented from completing, must become a part of the printed record of the meeting.

The papers read and discussed at this session were:

Iron Making in India, by J. D. Weeks, of Pittsburgh.

"Ore in Sight," by Professor Persifor Frazer, of Philadelphia.

The Action of Sewage Water on Boilers and Condensers, by Professor C. O. Thompson, of Worcester, Mass.

On Wednesday, August 25th, excursions were made by special train on the Marquette, Houghton and Ontonagon Railroad to the Republic, Champion, and Michigamme mines. At noon the members and their ladies were hospitably entertained at dinner by the ladies of Republic.* L'Anse was reached by train at 6 o'clock P.M., where the Northern Queen awaited the party.

EXCURSIONS IN THE PORTAGE LAKE COPPER REGION.

Local Committee.

EXECUTIVE.—J. N. Wright, chairman; E. H. Tower, treasurer.

RECEPTION.—B. F. Emerson, J. R. Devereaux, T. L. Chadbourne, M. B. Patch, Richard Uren, William Tonkin.

TRANSPORTATION.—James R. Cooper, C. E. Holland, Edward Ryan, Captain Tonkin.

FINANCE.—J. N Wright, John Daniell, Z. W. Wright, E. H. Tower.

REFRESHMENTS.—Captain J. Vivian, Colonel C. B. Grant, T. Cullyford, James R. Cooper, Richard M. Hoar.

At 3 o'clock Thursday morning the steamer left L'Anse, and arrived at Houghton about 7 o'clock. During the morning the copper smelting works at Hancock (Detroit and Lake Superior Copper Company) and the stamp mills of the Osceola and Quincy mines were visited. In the afternoon opportunity was afforded to go into the Atlantic, Franklin, and Quincy mines, transportation being provided from the lake by cars at the Atlantic mine, and carriages at the Quincy mine.

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* In addition to the courtesies received by members of the Institute from individuals in the Marquette iron region, they were indebted for hospitality to the following companies: Jackson Iron Company, Cleveland Iron Mining Company, Iron Cliff Company, Lake Superior Iron Company, Pittsburgh and Lake Angeline Iron Company, Republic Iron Company, Champion Iron Company, and the Michigamme Iron Company.

On Thursday evening a session was held on the steamer, when the following papers were read:

A Short Blast at the Warwick Furnace, Pennsylvania, by John Birkinbine, of Philadelphia.

An Outline of the Geology of the Lake Superior Copper District, by Professor W. H. Pettee, of Ann Arbor, Michigan, supplemented by remarks by Professor Roland D. Irving, of Madison, Wisconsin.

Some Copper Deposits of Carroll County, Maryland, by Professor Persifor Frazer, of Philadelphia.

On Friday morning a special train, provided by the Mineral Range Railroad, conveyed the party to the Calumet and Hecla mine, where facilities were afforded for inspection of the mine and machinery under the guidance of the officers of the company. At noon dinner was served in Schoolhouse Hall by the Calumet and Hecla Company. After dinner a special train of open cars conveyed the party to Torch Lake, where the stamp mills of the Calumet and Hecla Company are situated. Here the Northern Queen was in waiting, and conveyed the members, after inspecting the mills, back to Houghton. The evening was devoted to the subscription dinner at the Douglass House, in Houghton, after which, at 11 o'clock, the Northern Queen steamed out of Portage Lake on her way to the north shore.

Silver Islet Landing was reached on Saturday morning, and, while awaiting the return of the superintendent, a delightful sail was taken around Thunder Cape. In the afternoon the members were allowed to visit the Islet under the courteous guidance of Captain Richard Trethewey, Jr., general superintendent of the mine, and a limited number went underground. About 5 o'clock in the afternoon the north shore was left behind and the steamer resumed its course to Marquette.

A third session of the Institute was held on Saturday evening, when the following papers were read:

Notes on the Geology of Gunnison County, Colorado, by Professor Persifor Frazer, of Philadelphia.

The Silver Sandstone District of Utah, by C. M. Rolker, of New York; read by Professor Maynard.

Notes on Two New Processes for the Extraction of Nickel from its Ores, by H. M. Howe, of Boston.

Owing to delays by fog the steamer did not reach Marquette until noon on Sunday. After an hour's stop the trip was resumed to the

Sault Sainte Marie, which was reached at an early hour Monday morning.

The fourth session was held on Monday morning. The papers read were:

Rail Specifications and Inspection, by C. P. Sandberg, of London, England, read by Dr. C. B. Dudley.

Notes on the Early History of Copper Mining on Lake Superior, by Martin Coryell, of Lambertville, N. J.

Notes on Various Forms of Ports for Gas Melting Furnaces, by P. Barnes, of Springfield, Illinois.

The Weight, Fall, and Speed of Stamps, by Professor H. S. Munroe, of New York city; read by Professor Pettee.

The final session was held on Monday afternoon. The papers read were:

Relations of the Graphite Beds of Chester County, Pa., to the Geology of that County, by Professor Persifor Frazer, of Philadelphia.

The Chemical Reactions in the Bessemer Process, the Charge containing but a Small Percentage of Manganese, by Charles F. King, Newport, R. I., read by the secretary.

Notes on Two Scaffolds at the Cedar Point Furnace, by T. F. Witherbee, of Port Henry, N. Y.; read by Mr. Birkinbine.

A Flux for Rolling Mill Cinder and Silicious Iron Ores in the Blast Furnace, by Dr. J. P. Kimball, of Bethlehem, Pa.; read by the Secretary.

Note on a Direct Process for Treating Fine Iron Ores, by W. E. C. Eustis, of Boston.

The following papers were read by title:

Mica Mining in New Hampshire, by Professor C. O. Thompson, of Worcester, Mass.

Copper Refining in the United States, by Professor T. Egleston, of New York city.

A Glossary of Mining Terms, by Dr. R. W. Raymond, of New York city.

The Self-fluxing Properties of Chateaugay Magnetite and its Treatment in the Blast Furnace, by Dr. J. P. Kimball, of Bethlehem, Pa.

The following persons proposed for members and associates of the Institute were then unanimously elected.

MEMBERS.

William H. Adams,	Dixon, Ill.
William F. Almy,	Chicago, Ill.
Walter U. Barnes,	Worcester, Mass.
John D. Boyd,	Uniontown, Pa.
William A. Bray,	Quinnesec, Mich.
H. A. Burt,	Marquette, Mich.
John W. Cabot,	Johnstown, Pa.
Alonzo Clarence Campbell,	Nashville, Tenn.
Maxwell Chapman,	Pittston, Pa.
William Chauvenet,	Newport, R. I.
John Cliff,	Hancock, Mich.
Frederick G. Coggin,	Lake Linden, Mich.
Theodore B. Comstock,	Eureka, Colorado.
Augustus L. Crocker,	Springfield, Ill.
R. F. J. de Peiger,	New York city.
Isaac Eckert,	Topton, Pa.
John P. Edwards,	Cleveland, O.
John D. Evans,	Chester, N. J.
B. F. Fackenthal, Jr.,	Riegelsville, Pa.
Michael Fackenthall,	Hellertown, Pa.
Charles G. Francklyn,	New York city.
Frederick W. Gordon,	Pittsburgh, Pa.
Francis N. Gove,	Dover, N. J.
George S. Griffen,	Phœnixville, Pa.
J. K. Griffith,	Nicetown, Philadelphia.
George H. Hewitt,	Lead City, Dakota.
Edward S. Hutchinson,	Cannelton, W. Va.
E. K. Hyndman,	Connellsville, Pa.
Charles F. King,	Newport, R. I.
J. S. Lane,	Akron, O.
B. C. Lauth,	Pittsburgh, Pa.
William J. March,	New York city.
G. C. Marshall,	Uniontown, Pa.
William L. Neill,	New York city.
Earl W. Oglebay,	Wheeling, W. Va.
Jacob H. Opperman,	Canal Dover, O.
John W. Plummer,	Fairplay, Col.
W. D. Rees,	Marquette, Mich.
William L. Richards,	Blossburg, Pa.
Charles L Rogers,	Rocky Bar, Idaho Territory.
Pedro G. Salom,	Altoona, Pa.
Arthur W. Sheafer,	Pottsville, Pa.
John M. Sherrerd,	Secaucus, N. J.
Frederic W. Simonds,	Chapel Hill, N. C.
John William Skiles, Jr.,	Gothic City, Colorado.
W. A. Smalley,	Georgetown, Col.
George Edward Thackray,	Springfield, Ill.
David H. Thomas,	Alburtis, Pa.
Jacob Traber,	Cincinnati, O.
Herman Veeder,	Plattsburgh, N. Y.

John Webb, Jr.,	Gouverneur, N. Y.
Bard Wells,	Pottsville, Pa.
Sydney B. Wight,	Detroit, Mich.
Frederick H. Williams,	St. Louis, Mo.
Bailey Willis,	Newport, R. I.
L. S. Woodbury,	Calumet, Mich.
Charles E. Wright,	Marquette, Mich.

ASSOCIATES.

Augustus C. Brown,	Marinette, Wis.
Alfred Daniel Churchill,	Davenport, Iowa.
William O. Comstock, Jr.,	St. Louis, Mo.
Solomon S. Curry,	Vulcan, Mich.
Jefferson Day,	Vulcan, Mich.
James M. Ferguson,	Philadelphia.
Howard V. Furman,	New York city.
William H. Harvey,	Cleveland, O.
J. H. King,	Painesville, O.
Herman Kobbé,	New York city.
David McKee,	St. Louis, Mo.
George Merryweather,	Chicago, Ill.
J. W. Mills,	Pittsburgh, Pa.
Frank Nicholson,	St. Louis, Mo.
George C. Stone,	St. Louis, Mo.
P. A. Taylor,	Pottsville, Pa.
John M. K. Wickersham,	Philadelphia.

On recommendation of the Council the status of the following associates was changed to member:

H. L. Bridgman,	Charles S. Hinchman,
James Constable, Jr.,	Frank Klepetko,
A. C. Fairchild,	John Shoenbar,
Austin Farrell,	A. Harnickell.
Y. Hasegawa,	

The President announced that it was generally understood that this Lake Superior meeting was intended to take the place this year of the usual May and October meetings, but it might be considered desirable to have this change authorized by the Institute. On motion of Mr. J. D. Weeks it was voted that this meeting be considered to represent the two meetings ordinarily held in the spring and fall.

The Secretary gave notice of a proposed change in Rule VI, with reference to circulation of notices.

Mr. J. C. Bayles spoke of the great cordiality and hospitality with which the Institute had been received in the different mining regions, and of the painstaking labors of the local committees in rendering our brief visit as profitable as possible in the publication

of special directories and pamphlets of local information. To one of our members who was not able to be present, Major T. B. Brooks, the members were much indebted for a large number of reports and maps relating to this region, and also to Mr. Charles E. Wright, of Marquette, for copies of the Annual Report of the Commissioner of Mineral Statistics of the State of Michigan for 1879. He then offered the following resolutions:

WHEREAS, The courtesies and favors which have been shown to members of the American Institute of Mining Engineers have been so numerous, that no resolution could be made sufficiently comprehensive to convey a suitable expression of our thanks to all who have placed us under obligations.

Resolved, That the Secretary be instructed to express the thanks of the Institute to all who have contributed to our instruction, comfort, or pleasure, and that copies of such letters of thanks as he may send be spread upon the minutes of this meeting as expressions of the deep sense of obligation felt by all who have availed themselves of the unusual opportunities of seeing the mineral resources of the Northern Peninsula, which this memorable excursion has afforded.

Resolved, That the Secretary be directed to convey the thanks of the American Institute of Mining Engineers to the president and officers of the Chicago and Northwestern Railway Company, and the Marquette, Houghton and Ontonagon Railroad Company, for the unusual favors extended to the members and ladies who have visited the Lake Superior mineral districts, and to convey to them the assurance that their kindness has been fully appreciated.

Resolved, That the thanks of this company are tendered to the captain and officers of the steamer Northern Queen for excellent management, and for efforts to contribute to the comfort of the gentlemen and ladies of this party.

Resolved, That the thanks of all who have participated in this excursion are due to Messrs. W. P. Shinn and J. D. Weeks, to whose persistent efforts to overcome the many and serious difficulties encountered we owe the complete success of this excursion, which enjoys the unique distinction of having been carried out according to programme, without accident, and with a measure of comfort which could not have been enjoyed under any other circumstances.

On being put to vote by Mr. Bayles these resolutions were carried with enthusiasm and applause.

After a delightful sail through St. Mary's River, Mackinaw was reached about 6 o'clock on Monday evening, where a stop of an hour was made. On Tuesday morning about 8 o'clock the steamer arrived at Escanaba, where the members were received by the

Local Committee in the Menominee Iron Region.

N. P. Hulst, chairman; A. C. Brown, John R. Wood, S. S. Curry, John Perkins, Thomas Roberts, George E. Stockbridge, John L. Buell, Carl L. Wendel, J. Day, D. H. Wood, E. P. Foster, J. F. Atkinson, James Tobin, Alexander Kempt, S. H. Selden, W. B. Linsley, G. M. West.

Bidding farewell, with regrets, to the Northern Queen, which had

A FLUX FOR ROLLING MILL CINDER AND SILICIOUS IRON ORES IN THE BLAST FURNACE.

BY DR. JAMES P. KIMBALL, BETHLEHEM, PA.

AMONG the curious results of the recent advance of prices in the iron trade of the United States, one of them at least is to be regarded as of great importance. I allude to the utilization of mill cinder as a cheap and almost costless substitute for high-priced iron ores in many blast furnaces, situated within easy reach of such raw material. It has been, with but few exceptions, the practice in this country, based upon tradition rather than upon authority or European precedents, to waste this material on account of its high proportion of silicic and phosphoric acids, although known to contain more iron than most ores, and although also known to be sometimes applied to the blast furnace in greater or less quantities without serious detriment to the iron for specific purposes. While in use to a limited extent in the Hocking Valley and Hanging Rock iron regions of Ohio for several years, its use in Western Pennsylvania has only become general of late, under the exigencies of high prices and a short supply of ore. Especially has mill cinder largely entered into the stock of furnaces attached to rolling mills in and about Pittsburgh. Under such circumstances the cinder pig has been puddled on the premises, and the malleable iron produced has been unexpectedly good.

Cautiously as at first mill cinder has been applied, it is evident that the temptation to use it freely is a strong one whenever the commercial rates for high-class ores are out of proportion to the general conditions of the iron trade, as sometimes happens in this country, especially as the free use of it is apparently justified by the quality of the iron produced from this cheap and abundant material. Indeed the consumption of cinder pig has not been wholly confined to mills using up the production of furnaces belonging to the same plant. One furnace at least on the Ohio, at Covington, for several months has been making foundry pig from "all cinder." The iron has gone into the general trade.

It is probable that malleable iron of good quality can be made from the poorest cinder pig, but with what degree of economy will

depend on the relative cost of good ores, of labor, and of fuel. At works producing and puddling their own cinder pig, all evils of practice are encountered at the puddling stage of the manufacture.

But it is doubtful whether the prejudice against the use of cinders, and the valid reasons against their indiscriminate application to the blast furnace, are not sufficiently strong to exclude from the general trade either forge or foundry-cinder pig without its effectual amelioration in the blast furnace itself, except possibly in the case of foundry iron for a few specific purposes, where excessive cold-shortness is not regarded as a serious objection, as when used for gas and water pipes, stove castings, etc.

The recent improvements in the basic processes for the purification of crude iron point to the special adaptation of phosphoric pig for these particular processes, and the application of cinder pig *par excellence* in preference to purer and more costly iron.

The results of the recent introduction of cinder into the stock of Pennsylvania furnaces running on forge iron have varied, as near as I can learn from personal inquiry, according to what appears to me to be the accidents of the several mixtures in different cases.

ANALYSES OF MILL CINDERS.

	TAP CINDER.			REHEATING OR FLUE CINDER.	
	I.	II.	III.	IV.	V.
Silicic acid	13.81	30.00	21.58	29.60	24.51
Protoxide of iron	64.53	65.04	68.38	64.67	63.30
Sesquioxide of iron	8.73				
Protoxide of manganese	0.36	1.60	trace.	trace.	trace.
Metallic iron			7.12	2.35	6.80
Alumina	2.01	1.20	0.30	2.40	0.35
Magnesia	0.44	trace.	1.50	trace.	1.40
Lime	4.28	0.20	2.10	0.44	2.50
Phosphoric acid	4.37	1.24	3.20	0.54	0.83
Sulphuric acid	0.62	trace.		trace.	
Total	99.15	99.28	99.18	100.00	99.69
Metallic iron	53.44	50.59	51.42	52.65	51.10
Phosphorus	1.91	0.54	1.40	0.23	.36
Sulphur			0.33		

I. Rensselaer Mill, Troy, N. Y.—Tap cinder.
II. Ironton Rolling Mill, Ironton, Ohio.—Tap cinder.
III. Marietta Rolling Mill, Marietta, Ohio.—Tap cinder.
IV. Reheating (flue) cinder—same works.
V. Reheating (flue) cinder—same works.

The proportion of cinder being the same, the best results have been obtained with aluminous mixtures, *i. e.*, when used along with ores containing notable proportions of silicate of alumina, like clay

ironstone, or Clinton fossil ore, or, still better, of uncombined alumina, as in French beauxite and in Belfast (Irish) ores. This experience is in agreement with the best European practice.

Reference may be had to analyses of tap cinders at English works, given by Percy, and also to examples of reheating cinders (*Iron and Steel*, 668, 724. See Wedding's Percy, III, 230 *et seq.*).

As both vary in acid properties to about the same degree, according to the relative proportion of silicic acid and ferrous oxide, the relative proportion of a mixture of both as a blast-furnace stock may practically be disregarded.

The cinders, although varying in their proportions of silica, are as furnace stock all highly acid. They are also high in phosphoric acid from the oxidation of phosphorus in the process of puddling and from its consequent concentration.

The two tendencies to be overcome in the use of mill cinders are, first, the production of a silicious metal through the reduction of an excess of silica and its passage in the metallic state into the pig; and, second, an excessive cold-shortness from excess of phosphorus, the same effect being likewise produced by excess of silicon.

In producing malleable iron from cinder pig, phosphorus is sufficiently oxidized and slagged off within the ordinary limits of the operation of puddling, and therefore without sensibly prolonging this process. Silicon on the other hand is eliminated in the same way, but not without retarding the operation, and consequent loss of iron and fuel. Hence the necessity of reducing the proportion of this element in the pig.

If cinder from the puddling of cinder pig be used continuously it will readily be seen that at works where this is done a deterioration of the cinder must be the result, by accumulation of phosphoric acid. Thus the proportion of phosphoric acid in the cinder dump will increase with the frequency that cinder is used over.

In producing cinder pig for foundry purposes cinders should not be used more than once, unless care be taken to divert the excess of silica and phosphorus from the iron to the slag of the blast furnace. Where this is the aim, it becomes of the last importance to keep down the proportion of silicon in the pig, already cold-short from excess of phosphorus. That this can easily be done by various admixtures I shall presently show.

So far as I can learn the practice has uniformly been in this country to neutralize the excessively acid quality of cinders by excess of lime-

stone, while certain ores have been in favor for admixture. Such ores prove to be either red-short basic ores, like Lake Superior specular, or highly argillaceous ores, like clay ironstone from the coal measures.

In Great Britain, where the utilization of mill cinders is well understood, an aluminous admixture is considered indispensable. Several clay ironstones are especially used for this purpose, fire-clay, ferriferous shale, and, *par excellence*, an aluminous ore from Belfast, Ireland,—a hydrous brown hematite, containing 35 per cent. of *free alumina*, and not over 32 per cent. of metallic iron. This ochreous ore of alumina is very near the French beauxite, which is even richer in alumina.

Belfast ore is well known in this country, it having been imported by several furnaces in Pennsylvania for the sake of its aluminous qualities, so deficient in most American magnetites. Chateaugay magnetic iron ore, from Clinton County, N. Y., a feldspathic type of this class of ore, doubtless owes its extraordinary fluxing properties to its large proportion of alumina, which is of course already combined with silica (monosilicate).

SILICIOUS IRON ORES.

Many of the most important and best-known iron ores of the United States low in phosphorus are high in uncombined silica, and hence have a tendency to excessive silicon in the pig.

The following analyses of well-known Bessemer ores will illustrate this point:

	I.	II.	III.	IV.
Sesquioxide of iron	50 13	55.60	42.09	43.37
Protoxide of iron	23.29	25 24	19.10	16.55
Protoxide of manganese	0.38	0.31	0.32	0 24
Silica	20.02	17.44	20.04	26.01
Alumina	4.22	1.09	7.90	3.25
Lime	1.28	0.53	7.87	3.02
Magnesia	0.85	0.12	2.46	7.56 ($CaCO_3$)
Sulphur		trace.	0.32	0.17
Phosphoric acid		0.05	0.21	trace.
Titanic acid	trace.			
	100.17	100.38	100.31	100.17
Metallic iron	53.16	53.53	44.31	43.28

I. Crown Point Iron Company, N. Y., Hammond Mine. Run of Mine.
II. Crown Point Iron Company, N. Y., Penfield Mine, Run of Mine.
III. Mount Hope Mine, Washington County, N. Y.
IV. Port Ann Mine, Washington County, N. Y.

—*Jour. Iron and Steel Inst.*, 1874, p. 130.

ALUMINA AS A FLUX FOR SILICA AND LIME.

It is well known that a large proportion of lime in the blast-furnace charge is the most uniformly available means at hand for the diversion of sulphur from the iron to the cinder. But the tendency of an excess of lime in the blast furnace is to a refractory or difficultly fusible cinder. Likewise, the most available means for preventing the reduction of silica in the use of an acid stock, like silicious ores or mill cinders, is the application of a large proportion of lime in the charge.

It has long been generally observed that the admixture of aluminous iron ores, like clay ironstone, promotes the fusibility of basic slags; and that, with an aluminous mixture, a large proportion of lime may be charged when desirable, with the object of preventing the passage of silicon and sulphur into the iron. Thus Fremy obtained perfectly fused aluminates of lime with 80 parts of lime and 20 parts of alumina, and again with 90 parts of lime and 10 parts of alumina.*

One of the most striking tendencies in American blast-furnace practice is the use of an excess of lime, especially at the East, where the only aluminous ores generally in use are native clayey hematites and a few feldspathic hematites. Limestone is too often, against the fusibility of cinder and contrary to economy, made to do the duty of much less proportions of *alumina*.

The deficient slag-making properties of our richest ores are often mistakenly supplied with excess of lime, the best effect of which must sometimes be simply to complement the variety of bases requisite for a good cinder from the magnesian and aluminous impurities of the limestone itself, instead of more economically adding the same substances directly in the ore mixture. The consumption of fuel must be in some direct proportion to the basicity of the cinder beyond a certain degree, when accomplished by limestone alone.

The comparative qualities of magnetites are often estimated practically, even if not by rule, according to their earthy, rather than by their metallic units. Thus several ores of this species in the market enjoy special reputations for smelting properties, due in all such cases to the proportion and quality of their silicious and basic contents, or cinder-making properties. Calcareous or carbonated varieties of ore, like spathic magnetites and clay ironstone or siderite, having self-fluxing properties, are not at present under discussion.

* Comptes rendus LX, 1865, 996.

It has been found that the English iron ores, producing iron with first-rate malleable properties, like Lowmoor, Blaenavon, and Staffordshire Gubbins, are those averaging 1 part of alumina to not over 2½ of silica.

It is these earthy constituents of ores, including magnesia, on which not only the slag-making properties of ores depend, but entering more or less into the metal, partially only in a reduced state, are in the course of manufacture given off in the form of cinder, the quality of which has a direct influence upon the formation of fibre, upon cohesion, or, in other words, upon the strength of the iron. The influence of sulphur and phosphorus in forge metal is comparatively unimportant.

Millions of tons of second and third class specular iron ores, already mined and stocked in the dumps of Lake Superior mines as refuse, can be afforded cheap for shipment. These ores will prove acceptable enough as soon as effective and economical means are found for overcoming their acid properties arising from jaspery admixtures (silex). These ores vary from 50 to 60 per cent. of metallic iron.

A cheap and available aluminous flux alone is required to bring this immense accumulation of really valuable ores into the market.

WESTCHESTER ALUMINOUS MAGNETITE AS A BLAST-FURNACE FLUX.

In 1874 I called attention to a highly aluminous non-silicated magnetite occurring in Westchester County, New York, under the usual conditions of the magnetic ore beds of the New York and New Jersey highlands, as especially adapted for the blast furnace in admixture with silicious iron ores, mill cinders, or sulphurous ores.*

Since then this deposit has proved to be of great magnitude, and to be so situated as to admit of this valuable ferro-aluminous and basic material being placed on board vessels at Peekskill, or on cars of the Hudson River Railroad, at the price of other iron ores in the market.

The following analyses of typical specimens exhibit its superiority as a material at once highly basic and ferruginous, and as the richest available source of uncombined alumina known, and at the same time as an iron ore but slightly below the standard of richness of well-known shipping ores.

* Amer. Chem., IV, 321.

ANALYSES OF ALUMINOUS IRON ORES.

	WESTCHESTER ALUMINOUS MAGNETITE (ANHYDROUS).						FOREIGN ORES (HYDROUS).	
	I.	II.	III.	IV.	V.	VI.	Belfast ore.	Beauxite.
Protoxide of iron	45.86		21.14	18.49	17.92			
Sesquioxide of iron			25.86	28.21	28.70		46.65	45.50
Bisulphide of iron	2.63							
Protoxide of manganese	0.55							
Alumina	39.36	41.28	44.58	36.46	34.47	39.23	23.96	39.50
Lime	0.47							
Magnesia	7.18							
Phosphoric acid	0.22		0 16	0.09	0.16			
Silicic acid	0.51	0.32	1.13	1.04	2.88	1.17	8.29	1.75
Titanic acid	2.41	3.90	3.88	3.52	4.41	38.24		
Water	1.18						18.71	12.57
Metallic iron	34 44	35.82	34.54	34.13	34.03	34.59	32.65	31.85
Phosphorus	0.09		0.07	0.04	0 07	0.067		
Sulphur	1.40							

I and II. Analyses by Professor C. F. Chandler, School of Mines, N. Y.
III, IV and V. Analyses by Professor T. M. Drown, Lafayette College, Easton, Pa.
VI. Average of preceding analyses.
Belfast ore, owner's circular.
Beauxite, Dr. Siemens.

From the above table of analyses it will be seen that the Westchester material is a mixture of magnetite and anhydrous oxide of aluminium. Belfast ore and beauxite, on the other hand, consist essentially of hydrated oxide of aluminium, together with variable proportions of hydrous and anhydrous sesquioxide of iron.

Owing to the large percentages of water in these foreign aluminous ores the Westchester material, weight for weight, has by far the greater number of available units. In the calcination of Belfast ore, or in the blast furnace, a shrinkage of about one-fifth takes place.

In Lancashire and Cumberland, England, where argillaceous fluxes have long been applied along with the rich red hematites of these districts, the ochreous hydrate of alumina, known as Belfast ore, has come into use as a substitute for common clay shale, the object of such a mixture being to supplement the deficient slag-making properties of so rich an ore, as well as to saturate the uncombined silica (the percentage of which is from 5 to 7), and thus to bring up the mixture to the same composition as the best clay ironstone.

Non-silicated aluminous ores, like the Westchester or Belfast ores, in which the alumina is in a free or uncombined state, are especially adapted to admixture as follows:

I. WITH SILICIOUS ORES, like quartzose magnetites, or silicious

hematites of all varieties—to prevent the reduction of silica and the passage of silicium into the pig metal.

Silicious iron ores may be brought to the same essential composition as the best clay ironstone, or feldspathic magnetite, by the addition of such a proportion of alumina as will reduce the silica of the mixture to about $2\frac{1}{2}$ parts to 1 of alumina.

The addition of *silicated* alumina, like shale, clay, or feldspathic magnetite, for the purpose of neutralizing excess of silica, defeats the production of a basic slag without excess of lime.

1. With free alumina it is practicable even with excessively acid ores to produce a slag between a monosilicate and a bisilicate.

2. The application of an excess of lime for the same purpose tends to a difficultly fusible cinder, slow working of furnace, and a waste of fuel.

II. WITH MILL CINDERS, for the same purpose and with the same effect.

The advantage of an application of free alumina to a highly silicious stock is well explained in a commercial circular, dated Bayswater, London, 1865.

In this circular it is shown that the result produced by the mixture of four tons of Blaenavon, Pontypool, and Lowmoor clay ironstone, in equal parts, is in like manner accomplished by applying *one ton of Belfast aluminous ore to four tons of the cinders*, and that there is no difference in the proportion of alumina to silica, or in the quantities of sulphur and phosphorus.

III. WITH MAGNESIAN ORES, like chloritic or hornblendic magnetites, *e. g.*, those of Northern New Jersey and Southern New York—to supplement their slag-making properties, and promote fusibility of cinder,—this being accomplished far more effectively and economically than with lime alone.

IV. WITH SULPHUROUS ORES, OR WITH SULPHUROUS COAL—to prevent the reduction of sulphates back to sulphides by retaining them in the slag. The action of alumina resembles that of lime, and in conjunction with lime performs desulphurization without excess of lime.

The difficult fusibility of a highly basic (calcareous) slag, such for instance as comes from an excess of lime in the case of a sulphurous stock, may be overcome by an addition of free alumina in the form of Belfast or Westchester ferro-aluminous ores; or, still better, by replacing a portion of the lime with at least this equally effective and far more fusible absorbent of sulphur when applied in proper relation to silica.

ESSENTIAL COMPOSITION OF MIXTURES OF SILICIOUS IRON ORES AND MILL CINDERS WITH WESTCHESTER ALUMINOUS MAGNETITE.

	Iron.	Alumina.	Silica.	Magnesia	Phosphorus.	Proportion of Alumina to Silica.
5 parts Crown Point (Hammond Mine) to 1 part Westchester Ore.	50.06	9.28	16.88	1.90	0.011	1 to 1.82
5 parts Crown Point (Penfield) to 1 part Westchester Ore.	54.54	7.44	14.73	1.39	0.029	1 to 1.98
5 parts Fort Ann Magnetic Iron Ore to 1 part Westchester Ore.	41.80	9.247	21.87	1.19	0.011	1 to 2.25
7 parts Mill Cinder (I), Rensselaer Rolling Mill, to 1 part Westchst'r Ore.	51.12	6.66	12.23	1.28	1.67	1 to 1.82
3 parts Mill Cinder (II), Ironton, Ohio, to 1 part Westchester Ore.	46.59	10.71	22.50	1.80	0.422	1 to 2.10

THE SILVER SANDSTONE DISTRICT OF UTAH.

BY CHARLES M. ROLKER, E.M., NEW YORK CITY.

THIS remarkable and well-known district lies about 320 miles south of Salt Lake City, in Washington County, near the Arizona border of the territory. It is now reached by the Utah Southern Railroad and its extension, and the last 100 miles are run by stages. These vehicles are called "jerkies" in the West, which name conveys a good idea of the comfort they afford, and the relief experienced when you alight.

Arriving at Silver Reef, the main camp of the district, one sees at once that he stands where once a surging sea had its domain, marked now by heavy sandstone deposits of a red and white color. The town itself, a neat, clean, and orderly mining town, is encircled on the north by trachyte and granite mountains, skirting to the west. They are cut through in places by deep gorges, left us as the only trace of the force of former currents, which drained the adjoining territory to the north; and which when swelled and infuriated by tempests and cloud-bursts, took in their grasp the huge blocks of

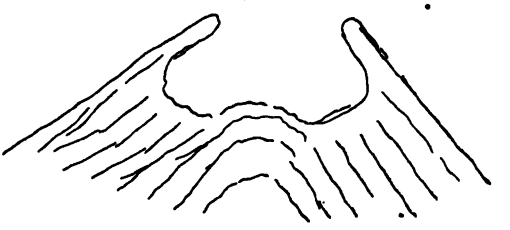
granite and trachyte, which now lie scattered about as boulders, to the north, west, and east of the town.

At the base of these encircling mountains lies a belt of dull, brick-red sandstone, over 1000 feet thick. Its extent is seen on the west side of the town, and its trend is for over 30 miles to the south. Following the northern sandstone arc it flanks to the east and south, gradually sinking into the ground until the volcanic lava caps and nearly covers it, leaving protruding masses like frowning rocks in a fiery sea. The whole belt takes the shape of a horseshoe. Back of these red sandstones, on the east and northeast, high sandstone table-lands extend, of variegated colors, from white, to gray, to yellow, beautifully banded, looking in the distance like formidable castles; a romantic picture in the glow of a setting sun.

Turning to the south of the town, we see a standstone hill, about 1½ miles distant, which, through the action of volcanic forces, stands now boldly several hundred feet above the town's plateau. Underlying, as it formerly did, the surrounding sandstone country, it has since acted as a central wedge, around which the other strata have been grouped. Conformable to its east and west slopes, we see the strata dipping east and west, with a varying inclination of from 15° to 35°, striking in a northeast and southwest direction. On either side of this wedge we find a series of superimposed sandstones. They are best marked on the west slope of the hill, where they follow in regular series—white sandstones, underlaid by gray and red sandy shales, separated in places by green clay shales, and followed in turn by the white sandstones, the first of the second series. These white sandstones being harder have withstood the weathering action better than the softer underlying shales, and their strike is clearly marked by protruding ribs or reefs, the intervening shales being washed and carried away to a depth of over 100 feet, forming a valley. Of these reefs we note three: the White, the Buckeye, and the Butte Reef, overlying each other in the sequence named. Like the red sandstone before mentioned, which has the shape of a horseshoe with the open side on the south, so these reefs are grouped uniformly about the wedge above mentioned.

Following the course of the reefs in detail, in the immediate neighborhood we see the White Reef southwest of Silver Reef, as far as the eye can reach, and coming northerly to location No. 1, we find it boldly marked, all the way through the Thompson and McNally leads into and through the Barbee and Walker mines, with a dip to the west varying from 20° to 35°. Going along the northern curve, we find

it marked by the Lunar and Homeward-bound claims, dipping northerly and northeasterly. More or less denuded, we find it dipping to the east again, at the head of what is called Grapevine Wash. It is easily traced along the Wash to the Vanderbilt Claim, continuing shortly after under the basalt caps, until it is again laid bare and proved by the ore taken from the Duffin, Gibfried, Toquerville, etc., claims, all situated on the eastern branch of the horseshoe, where the strata dip east until the Rio Virgin cuts through them. Beyond the river it is again seen rising in places over the level of the volcanic beds and conformable to the east rib of the Harrisburg Gap. This gap is a portion of the central wedge, with its backbone scooped out, pot-hole like, and its hollowed washed sides left standing, dipping east and west, as in the accompanying sketch.



On this extreme south end of the eastern horseshoe arm of the White Reef, so far no silver has been found, while on its southwest arm low-grade ore has been found in places, up to and past the town of Harrisburg and St. George, a distance of over 20 miles. What I have said of the White Reef holds nearly true for the Buckeye Reef, an underlying stratum. From the top of the wedge-like hill, north of Harrisburg Gap, it can be seen making the horseshoe curve, within the White Reef. It is proven by the Silverflat, Michael, etc., to Chlorider's Chief, and past it; continues washed and disturbed at the northeast curve, until it comes to light again at the head of Grapevine Wash, within the White Reef horseshoe. From here it continues, at times prominent, but more washed and buried, until it passes the Vanderbilt Claim, on the White Reef. It is soon seen, cutting the road leading to the Stormont mill, near where the basalt cap is, and continues from thence forward, boldly and well-marked, until the Rio Virgin cuts it, I should judge about 400 to 500 feet west of where the White Reef sets through the river. Beyond the river it is mostly buried, but its southern trace can be seen from the east rim of "Little Purgatory Basin" (a scooped out

pot-hole north of Harrisburg Gap, in the central wedge), looking in the direction of the Stormont mill, and descending the slope to the river in the same direction. Turning to the west branch of the Buckeye Reef horseshoe we see traces of it west of the town of Harrisburg, but sufficient to mark out its line. Buried, or rather denuded, for some parts, it is plainly seen under the McMullin, and continuing on its northward course, it traverses the Emily Jane, Stormont, etc., claims, until we complete the horseshoe by striking again the Silverflat claim. The Butte Reef, underlying the Buckeye Reef, lies within the latter's circuit, being prominently marked on its west and northwest sides, while its east flank probably lies with its top washed in the Grapevine Wash Ravine. On the Butte Reef two or three claims have at times yielded well, but at present hardly any work is being done on it.

I have purposely been explicit in describing the circuits of the reefs, because the theory has been advanced that the Buckeye and Butte reefs were in turn faulted from the "original" reef—the White Reef, on its west side, and that only one reef existed on the east side of the horseshoe. Aside from the fact that two reefs are seen on the entire circuit, there are other reasons which speak against a *one*-reef theory. With their sides 300 to 1500 feet apart, gradually widening until the gap is about 4000 feet, or more, at the head of the curve, it would be a very strange fault if we assumed it to have fallen off the White Reef, in the shape of a horseshoe. But, again, underlying the White Reef is the Pride of the West Ledge, a silicious limestone, very plainly marked, and to be seen distinctly at the first glance, all along the White Reef. This marked distinctive bed is absent in the Buckeye Reef. Further, the character of the Buckeye and White Reef ores is as different to the experienced eye as dark blue is from purple, and they act differently in the mill.

As to the age of the sandstones, little can be said with certainty, since so far no characteristic fossils have been found in them. Reeds and rushes are plentiful, but no leaf or shell has been traced to this locality. I have in my possession some fossil nuts and seeds, and what appeared to me at the time I found it an imperfect piece of a shell, but as my box of specimens has not yet reached me, and as I packed them up with the intention of identifying them after coming East, I will leave a discussion of them for a future occasion. My opinion is that the sandstones are Triassic.

The reefs themselves are made up of whitish-gray and red to red-

dish-brown sandstones, and between the reefs lie beds of clay shale, varying in color from blue to green to cinnamon brown. The ore occurs in similar strata of sandstone and clay shale. The roof is generally marked by a reddish micaceous sandstone, while the floor is made up of an arenaceous sandstone of a whitish color, with argillaceous sands underlying. The outcrop of the ore is marked on the east face of the reef, with the exception of those places where the former apex of the reef has been washed off, as in portions of the Buckeye Reef on its northwest side of the horseshoe. The ore is by no means confined always to one bed, but it is limited to a silver zone of from 30 to 90 feet wide, horizontally measured, and anywhere within this belt the horn-silver is liable to be found. As a rule it is more concentrated in certain layers (beds) of this belt, but in places it is so scattered as to bring the grade down to a uniform $10, which at present does not pay to work. Frequently, also, the ore is thrown in consequence of very fine slips from one bed into another. Hence the giving out of the ore in one bed is not exactly a discouraging fact, for a cross-cut may, and very often does, prove it to have jumped into a lower or higher bed respectively. In other words, the argentiferous sandstone belt is compound in structure. The producing branches, two or three in number, run together in places, at least two of them do, and then again continue for long distances with barren strata between, which vary in thickness from 3 to 15 and even 30 feet or more. In the depth, or following the dip, they have kept pretty well their own ground, but I have no doubt that what is now considered two and three separate beds will at a greater depth form but one bed throughout. The producing branches in all the mines change occasionally from a sandstone to a clay shale, even in the same bed, but certain portions of the reef, especially the northwestern portion of the Buckeye Reef, and the southern, and a part of the central portion of the White Reef, show a preponderance of clay shale and argillaceous sandstone. The latter strata are also found in some of the northern parts of the White Reef.

Of course the less clayish or argillaceous the sandstones the less slimes are produced in the mill. The southern, and part of the middle portion of the Buckeye Reef, show less frequently vegetable remains than the remaining portion and the White Reef, and in parts these remains are absent. In other parts, and this holds true for the whole district, we find the producing sandstone beds underlaid by a stratum of highly argillaceous sandstones of variable thick-

ness of from 10 inches to 2 feet, which carry much silver, and frequently show solid sheets of horn-silver along the seams of the thickness of a knifeblade. I have known such seams to mill right along from $60 to $130; unfortunately their occurrence is not as frequent as might be wished.

The ore itself is what is known as cerargyrite or chloride of silver, which, however, below true water-level will change to the sulphuret of silver, with native silver in places. Of the latter change two indications have been met with. A tested sample yielded in a certain mine only 65 per cent. of chloride of silver. This proportion will decrease in the ratio as water-level is passed, and the ore gets more outside of the reach of waters charged with oxygen and chloride of sodium. The grade of the camp is probably $20 to $25, though I have mined portions of beds which averaged right along $35 to $55, and others run as low as $14 to $17; and at times even $8 and $10.

The question of how the silver came into the sandstone has been discussed quite frequently in the camp, as may be imagined, and also among experts. The theory of contemporaneous deposition with the sandstones is held by some, while others hold that it has been deposited from ascending mineral solutions or vapors. I advocate the latter theory. I admit, at the first glance, one may be inclined to assume a contemporaneous deposition, inasmuch as the rushes and reeds, coated and partially replaced with horn-silver, are plentiful, and a cursory examination may show in certain localities the silver to be confined solely to places where we find organic remains. However, such is not the case, taking the district as a whole. I have seen and mined portions in these beds, for a stretch of 200 consecutive feet, which were really absolutely void to the eye of organic remains, and still milled an average of say $30; in spots as low as $20 and as high as $45 and $53. The carbon may, it is true, have been consumed by chemical action.

But grant for a moment that the silver was deposited contemporaneously with the sandstones. The first question to present itself would be, how did the silver get into the former sea? From what source did the silver come?

The surrounding border mountains have so far not been so kind to the prospector as to reveal any source of silver, and further north we find either gold or lead mixed with the ores containing silver. Now, then, if the silver was dissolved by the waters, and precipi-

tated by the decomposing vegetable remains, why not the lead and the gold, of which not a trace is to be found? Why is the silver limited to zones, outside of which no silver can be found? By this theory the silver should occur indiscriminately over a large area instead of being confined to limited belts, in close proximity to former volcanic centres, as at the reef, and in the district near Virgin City, upon North Creek,—a locality less well known. Such, however, is not the case. Further south we find the same beds carrying copper ores in rich quantities, a fact hard to account for under the theory of contemporaneous precipitation from above. The perfect and distinct occurrence of ore shoots, in the different producing beds, one shoot underlying the other, separated respectively by 4 and again 30 feet of barren rock, is likewise hard to explain by this theory. I refer to an instance in the Buckeye mine, near the Gad shaft, where there are three distinct producing branches, the top one being separated from the second one by 4 feet of barren rock, and the second one from the third one by 30 feet of unproductive ground, with a well-marked shoot in each, one overlying the other. I cannot see how it is probable that a current in one locality should be at one time charged with silver so as to deposit argentiferous rock, and then again free from silver and deposit barren rock, as would be indicated on the theory of contemporaneous deposition by the alternations just mentioned.

We find in the same line of bedding strata holding petrifactions from 6 inches to 3 feet thick, which contain no silver ore, while above and below it silver is found in good permanent grades in strata showing a scarcity of vegetable remains. Again, I have seen a stratum where the upper two feet assayed about $30, then 6 inches assaying $100 or more, then 15 inches barren, and below it a layer of $20 rock, all of the strata being full of petrifactions.

Another frequent occurrence, is a foot or two-foot seam of sandstone, full of petrifactions, charged with red oxide of copper, azurite, and malachite to some extent, and carrying no silver, while below it, good paying ores were found free from copper, or in places barren rock. Such a copper cap has always been found a good indication for an ore body near by, and drifts which I started on this indication have since opened finely. As another matter of interest, I found the seams, in which the vegetable remains are covered with autunite, which is quite frequent around the Gad shaft, and the two carbonates of copper, unproductive, with pay seams frequently above and below them. From these and other facts, I form my opinion,

that the sandstones and silver have not been deposited at the same time, nor the ore deposited by precipitation from metallic solutions passing in from above, after the sandstones had been tilted—a theory occasionally advanced.

At the time of the volcanic disturbance, metallic solutions, probably accompanied by steam and vapors, ascended from below and percolated through these sandstone beds, which at that time were most porous. The pressure decreasing, the vegetable remains in some parts, ferruginous masses in others, precipitated the sulphurets of silver (and copper in places), while at other points the silver was no doubt deposited by evaporation, as neither of the two precipitants is found, the carbon having been completely consumed in decomposing the metallic salts. The upper portions, now changed to chlorides, are the result of surface waters, charged with oxygen and chloride of sodium, and the native silver found in places is the result of decomposition of the sulphurets. As at Steamboat Springs to-day, where thirteen distinct openings (springs), emit steam and metalliferous vapors, at variable distances from each other, so did we have in those days, different channels, which are now marked by the pay shoots. We can thus easily see how, according to the hardness and compactness of the sandstone beds, the solution percolated, 4 and 30 feet apart, in the same direction, forming three ore shoots one under the other, or how the productive branches run together and diverge again. As the thermal waters under pressure coursed through the lower strata of the earth, dissolving the silver from those rocks, portions of copper were dissolved with it from adjoining zones which gave rise probably to the copper deposits further south. In places along the reefs, these waters carried more copper in solution than in others, and through some molecular attraction, it seems as if the copper has more or less limited itself to certain permeable sand beds, while the silver has gone to the adjacent bed, according to the mechanical condition of the rocks, and, no doubt, the chemical nature of the precipitating agent. In places where the quantity of copper was but small in the ascending waters it has been deposited in the same bed with the silver.

As to the occurrence of copper in the silver bed I have observed a curious fact. If the copper present be azurite, or a grassy-green-looking malachite, the amount of silver in the bed will diminish, and it is a bad indication for the life of this particular shoot. If the copper presents, however, a pale, but lively green, with a bluish shade in it, as we often find the stain on quartzy ores, it invariably

improves the grade of the silver ore. You may call it "kind" and "unkind" copper. I substantiated this on both reefs, and the trained eye will tell it at a glance.

Other objects of interest in the beds are occasional pieces of vegetable matter changed into lignite, some of which will assay high in silver, and others again be free from it. They are, in instances, coated with native silver, and also intergrown in cases with pyrites, holding a very small amount of copper. In places trunks and branches of trees are found, some of which assay well, while others do not. The silver is not alone limited to the outside bark, but I tried pieces from the very interior of such branches, which I carefully washed and scrubbed, and they yielded as high as $40 in silver. I also noticed, in the Buckeye Reef, a six-inch seam of jasper, resting between sandstone and clay shale.

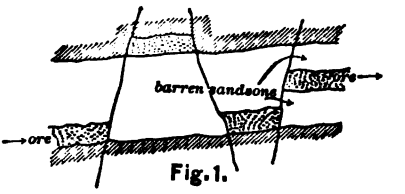


Fig. 1.

Slips are frequently met in the producing sandstone beds. Some of these slips are caused by very fine fissures or cracks, as fine as a sharp blade of a knife. They sometimes throw the ore into the over or underlying producing side branch. In some cases they also cause the silver to pinch out entirely as in Fig. 2. Often they are also the leaders to a new deposit. Faults are met with, which throw the silver-bearing stratum from a few inches to several feet within the same line of bedding, as shown in Fig. 1. The faulting lines are usually filled out with clay, and they generally contain silver. The faults and slips occur in all the mines. I append a sketch of two types, Fig. 1, being from the Buckeye mine, and Fig. 2 from the Last Chance mine.

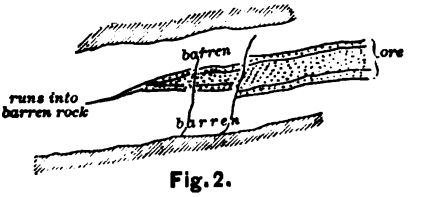


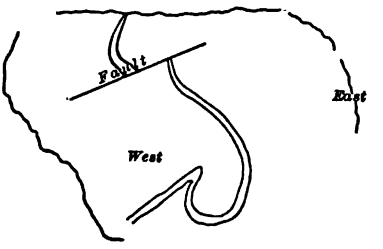
Fig. 2.

The silver solution seems to have left its traces in some of these faulting lines, being prevented, of course, from impregnating the immediate sides by the clay lining, until it found an easily permeable stratum above or below. The faulting lines were formed during and after the tilting took place and previous to the silver deposition.

In this connection, I may mention that the central portion of the Buckeye Reef, on its west branch, shows for about 400 feet in length a reverse dip (to the east), forming a complete curve following the

bed down on its dip, and showing the upper portion of this curve faulted 40 feet off to the west.

In the Kinner mine, in one place, it shows, besides, a doubling up before it assumes the regular west dip, as is indicated in the accompanying sketch. There are many other points of interest to be mentioned, but they would lead me too far.



I will add a few words of the early history of the camp, giving a few data as to the bullion production and the cost of working these ores. As early as April or May, 1875, a party came down from Salt Lake City, spent a few hundred dollars in prospecting, and left the camp in disgust. In the latter part of July, the same year, Judge Barbee came to reconnoitre the district. In September he returned to Salt Lake City to lay in supplies, and returned October 15th. He then prospected for thirty days on the White Reef, now the Gisborn claim, but without results. He then with two men started on the Tecumseh ground, which he located and named after the Indian chief. December 6th, 1875, he made his first shipment of 10½ tons of $502 ore; of course he sorted his ore. In forty-five days he made his second shipment, for which he received $7000. This he followed up with smaller shipments to Salt Lake City up to July, 1876, when, obtaining better rates in Pioche, he afterwards shipped to that place. Salt Lake charged the old Reno rates, and involved shipping rates of from $45 to $50 per ton, while the shipping rates to Pioche were $30 per ton. They allowed 70 to 75 per cent. of assay value, and charged $20 per ton beside for milling the ore. About $17,000 was realized on ore sold to Salt Lake smelters, and about $23,000 from the Pioche mills. Outsiders shipped to Pioche beside about $8000. Until October, 1876, probably twelve persons formed the entire population of Silver Reef City; the next month, what is known as the Pioche stampede, set in. From this time active work was done, as will be seen from the mills which were built. In February, 1877, the Leeds 5-stamp mill was started, followed in June, 1877, by the Stormont 10-stamp mill; and in October, of the same year, by the Pioneer 3-stamp mill. January, 1878, brought the Christy 5-stamp mill into operation; and in March, of the same year, the 5-stamp of the Barbee & Walker commenced

operations. This latter mill was burned down the 23d of June, 1879. It was, however, rebuilt and started the 27th of February, 1880. The Pioneer 3-stamp mill was closed in June, 1879, and subsequently taken down.

All of these mills, except the Leeds and Christy and the rebuilt Barbee & Walker mill, were built by home capital. There are four companies at work in the camp, Christy and Leeds being under San Francisco management, Barbee & Walker and Stormont under New York control. Outside of the four companies, the Kinner mine on the Buckeye Reef, and a few minor claims on the southern portion of the White Reef, are being worked by private parties. On what is termed locally the River Reef, the east branch of the White Reef's horseshoe, little work is being done at present, though a nice round sum of bullion has been made from the ore taken out of the Duffin, Gibfried, Toquerville, Jump Off Joe, Vanderbilt, and other claims, situated on this reef. High milling charges and royalties have been drawbacks in the early days of the camp to the poor prospector, and the present regular rates could be well reduced, namely, 80 per cent. of assay value, 20 per cent. discount, and $12 per ton for milling; returning only $52 from a $100 ore. In instances of big lots, the $12 charge has been reduced to $10 and $9. Mill assays govern of course.

The bullion produced by the camp was, up to June 1st, 1880, according to Wells, Fargo & Co.'s receipts, 2,755,247 ounces of fine silver. To this ought to be added the value of the bullion produced from the ore at Salt Lake City and Pioche. Disregarding this, however, we calculate that counting full time since each mill has been built (deducting of course the eight months the Barbee & Walker people were without a mill, and also the time since the closing of the Pioneer mill, allowing no time for stoppages and repairs, but counting the time each set of stamps has been running, and noting the number of stamps of the respective mills and reducing it to the standard of one stamp per day—30 days per month), the stamp capacity of this camp has averaged so far 111 ounces of fine silver per day—a remarkably high record for the camp, considering that all the mills had more or less stoppages during this time. But if the ore had not been in sandstone, this return could not have been made. The amount stamped is from 6 to 7 tons per head per day. If more than that is stamped, it is simply run into the slime pits, and not put through the pans. If only picked ore, from certain portions of the Buckeye Reef, were put through, probably 7.5 tons per stamp,

per day, on a month run, might be put through the Stormont mill, which has 13 pans to 10 stamps.

As mentioned in the beginning, some of the ore slimes more than others. The limits lie about between 5 per cent. and 33 per cent. I know of cases where 45 tons were stamped to get 30 tons for the pans. The folly of that is apparent, as settling-tanks are cheaper than the cost of hauling it out of the slime-pits, with the cost of having hauled it from the mine, and the interest on the money while it must lie in the pit, added to it. However, this is being remedied fast, by adding pans and settling tanks to the present plant.

The amounts of salt and bluestone used in milling are naturally very variable, according to the locality of the reefs from which it is taken. The limits probably lie between

Bluestone, $1\frac{2}{10}$ pounds to 5 pounds per ton.
Salt, 15 pounds to 50 pounds per ton.

The loss in quicksilver varies from $1\frac{1}{5}$ pounds to $2\frac{1}{2}$ pounds per ton.

The total cost of milling varies at the mills from $3.85 to $6 per ton, to which the cost of ore-hauling has to be added, except in case of the Barbee & Walker mine, which has no ore-hauling charges. All, except the Stormont mill, are steam mills; it is also the only 10-stamp mill of the district. The stamps in use, when new, weigh 750 pounds, and with a fall of 6 inches make from 80 to 100 drops per minute. The batteries have 40-mesh screens. The Stormont mill has 6 blanket sluices, 130 feet long, 14 inches wide, 5 inches deep, inclined under 3°,—the only one in the camp. The pans of the district are rated at a ton and a half. The fineness of the bullion varies from 700 to 987 fine.

Tailings vary from $3.25 to $10 per ton, varying with the localities in the different reefs. Slimes are generally richer than the ore from which they are produced. The cost of mining is likewise variable, depending on the condition of the mines, *i. e.*, on the amount of prospecting and deadwork to be done, or the construction required, and ranges between the limits of $4.50 to $9.50 per ton. The total cost of these ores, including bullion charges, ranges from $14 to $17 per ton.

Taking the camp as a whole, it shows very well indeed, and it must be ranked among our good camps. If the companies now operating there will work their mines legitimately and systemati-

cally, the camp will continue to be for a long time yet, what it is to-day, a sure and steady bullion producer.

DISCUSSION.

PROFESSOR G. W. MAYNARD: I have a word to say on the question of the age of the sandstone. I have examined an extensive district in the foot-hills of the Ural Mountains, in Russia, and there found sandstones that have the same appearance as these of Silver Reef. The sandstone there, as here, contains reeds and rushes, and silicified trunks of trees. I have noticed at Silver Reef, where organic matter occurs, that the ore at times is exceptionally rich in silver, while in Russia copper takes the place of silver. At Silver Reef there are no true fossils, but comparing the sandstones of Russia with those of Utah, I venture to suggest that they may be Permian. Mr. Rothwell, who made a careful investigation, calls them Tertiary; Mr. Rolker is of the opinion that they are Triassic.

I have another word to say in connection with the economical working of these sandstones, that is the difficulty of determining whether they contain any silver or not. The barren rock so nearly resembles in appearance the silver-bearing, that it becomes necessary to make anywhere from fifty to one hundred assays a day. The ores mill from $20 to $25 a ton. They crush very easily nine tons under each stamp. The district has already produced more than three million dollars, and it has only been working a little over three years. The monthly production is 135 to 150 thousand dollars.

SOME COPPER DEPOSITS OF CARROLL COUNTY, MARYLAND.

BY PERSIFOR FRAZER, PHILADELPHIA.

THE ore property of Mr. Augustus Roop is situated about one and a half miles south of the New Windsor Station of the Western Maryland Railroad, and is connected with the town of New Windsor by the Liberty and New Windsor Turnpike. It is about forty miles distant from Baltimore, and about seven miles west from the county town of Westminster, and a little more northeast from the celebrated Liberty Copper Mines. (See accompanying Maps 1 and 2.) The property comprises about 140 acres, lying principally

between two low ranges of hills, which rise over one hundred feet above water-level. The two properties together, *i. e.*, that of Mr. E. Stauffer and that of Mr. Roop contain, perhaps, 240 acres.

The junction of the lower Silurian limestone and the hydro-mica schists upon which it rests, so famous as the horizon of the larger portion of the limonite banks in Eastern Pennsylvania, occurs near the crests of the two low ranges of hills before referred to; so that the included valley, which shallows toward the south, is composed principally of limestone which the lower rocks inclose as in a trough. (See Sketch Map of property 3.) The whole tract referred to lies in Carroll County, Maryland.

The copper ore (of which analyses will be found below) is of two kinds: 1st, a rich band dividing the limestone from the apparently overlying, but in reality overturned and underlying schists, of from six to eighteen inches in thickness, and consisting of mixtures of the sulphides of copper, with a highly ferruginous red earth. This band occurs everywhere on the property that excavation has revealed this junction, and has averaged 23 per cent. of metallic copper.

2d. Various qualities of carbonates of copper, consisting of malachite and azurite permeate the limestone for a distance of from five to fifteen feet perpendicularly to the plane of junction before referred to. Wherever selected for analysis within this distance the limestone yielded 12 per cent. of copper.

For a much greater thickness than this the slacking property of the lime from this limestone is said to be seriously interfered with by the presence of salts of copper.

The existence of the copper was revealed by the excavations for quarrying limestone, and the largest of these is situated a short distance from Mr. Roop's dwelling-house. (Sketch Map 3.) A thin layer of deposition in this quarry seems to dip E. 15° S., 60°.

The cupriferous belt is at least five feet thick here, and even the nacreous schists themselves exhibit yellow and green stains of copper salts. This ore locality is called No. 1 on the Sketch Map (3). At the deepest part of the breast of limestone (seven feet below the general surface), the dip is E. 20° S., 60°.

About 150 yards northeast of the opening No. 1, and close by a springhouse, is a smaller opening, No. 2. The schists are here sandy and very much contorted. The dip, however, seems to be about E. 10° S., 72°.

About eight hundred feet, a little west of south of No. 1, are two smaller openings, marked Nos. 3 and 4. The same contact is here

found on the summit of the low ridge which is continuous between the two openings. The dip is about E. 30° S., 40°, and the schists are decayed sandy chloritic argillites. The rich ferruginous band previously mentioned is here about one and a half feet thick, while the impregnated rock seems to exceed its usual thickness of ten feet.

Mr. Foreman, the prospector of the deposit, states that he got very rich copper ore out of this opening. Bornite, chalcopyrite, and malachite are all to be found here, besides some gray copper. About two barrels and a half of this ore from No. 3 are said to have been sent to Pope, Cole & Co., of Baltimore, but with what result could not be ascertained.*

At an opening marked No. 4 the dip is about 45°.

The opening No. 5 is on the southeast range of hills on a projection of Mr. Roop's property into that next below. The quarry opens up the limestone here at about ten feet (geologically speaking) above the contact of the schists.

At this horizon the limestone is permeated with zinc blende, very much as is the case in the Saucon Valley near Bethlehem, and near Landisville on the Pennsylvania Railroad. The distance to which this impregnation of the limestone with blende extends is not accurately known, owing to the very imperfect development, but appearances are favorable to the presence of a rich and extensive mass of it. Besides the sulphide of zinc there is the usual rich ferruginous band of copper ore, and below it the cupriferous limestone represented elsewhere.

A sixth opening (No. 6 on Map) clearly bears the same relation to the opening No. 5 that No. 1 bears to Nos. 3 and 4, or in other words, it has been dug on the outcrop of the copper ore of the southeastern hill. Besides copper compounds and zinc blende are here found crystals of galena, and a three or four inch seam of oxide of manganese.

Manganese oxide and galena are also found at opening No. 5. A short distance south of No. 5, and just over the property-line which divides the properties of E. Stauffer and A. A. Roop, is a quarry in which copper ore is said to have been found many years ago.

On the northwestern hill at the point No. 7, which is close to Mr.

* On February 24th, 1880, about 454 pounds of the average output of a hole sunk a few yards southwest of hole No. 1, was sent to Pope, Cole & Co., who paid for it as 23 per cent. ore, according to the statement of Mr. Hutchinson. (See note.)

Stauffer's barn, there is a shallow ditch dug, in which unmistakable evidences of the presence of copper ores are found in the colored schists and limestone fragments profusely scattered around.

There seems to be no doubt, then, from the testimony of the rocks at Nos. 1, 2, 3, and 4, on the northwest hill, and Nos. 5 and 6 on the southeastern hill, of the existence of a continuous deposit of copper ore, in a sheet of which the first-named excavations represent one outcrop line, and the last two the other; and also, that besides the copper ore, there are masses of zinc blende and manganese, which occur near it.

The section placed at the upper right-hand corner of Map 3 will explain the view of the structure taken by the author. If this be correct the plate of ore, after making a shallow bend in the flank of the northwestern hill, dips under the valley between the two hills at a moderate angle, and after having sunk 300 or 400 feet below the lowest point of the surface emerges again with a steeper and reversed dip on the opposite (southeast) hill.

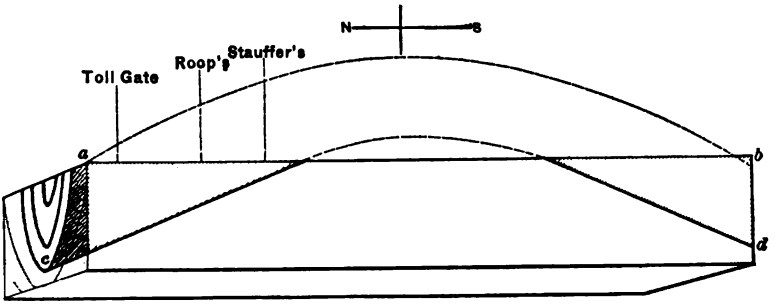
The section given in the lower left-hand corner shows the same beds, but with this difference,—that while it seems probable that the bending of the strata at the northwestern end of the northern section results in a shallow followed by a deep trough, with a narrow belt of barren schists dividing them, in the southern section the northwestern trough is the larger of the two, and the breadth of barren rock separating them has increased very much; and by this narrowing and shoaling of the ore belt a considerable quantity of it is lost.

This appears to indicate also that the ore *trough* itself rises towards the south, and explains (if well established) the fact that copper ores have not been reported as discovered between Mr. Roop's farm and the Liberty Copper Mines, distant about eight miles in the direction of the strike; for the lowest point of the trough of copper ore which is, say 350 feet deep at the northern end of Roop's property, is but about 175 feet at the southern end; or in other words, in a distance of 1000 feet south over the surface it has risen 175 feet, so that in double that distance or less than half a mile the bottom of the trough would reach the present surface, and in any greater distance it would rise above this. But this is but another form of saying that all portions of the ore body south of 2000 feet from opening No. 1 have been eroded and washed away. Of course this is understood to apply to these rocks only for that, at present, unknown distance within which the shoaling of the synclinal basin

towards the south continues. If the inclosing synclinal of schists again deepen in that direction it is an indication of the return to the earth, and, probably, the preservation within itself of that particular layer containing the copper ore.

The following small diagram may make this clearer. It represents an imaginary parallelopipedon cut out of the earth in the direction of the strike of the rocks. The line *a b* represents the profile of a certain extent of country in a northeast and southwest line. The shaded portion between the *a b* and *c d*, represents the side of the cupriferous trough as it would appear through the outer trough, could we look through such a great northeast and southwest slice in a southeast or northwest direction. The curves above *a b* represent the portion of the ore plate which have shared the general erosion which has moulded the surface.

If the structure here supposed is true their ought to be indications of copper to the north of the Roop tract, but only for a short



c d - Bottom of synclinal of copper deposit.
a b - Ideal line of present surface.

distance to the south. In confirmation of this view the absence of known ore between Stauffer's farm and the Liberty Mines is cited on the authority of the residents in Mr. Roop's vicinity. The other fact, *i. e.*, the existence of copper ores to the north, is attested by the record of a well sunk near a toll-house where copper ore was found at 75 + feet (?) (see Map 2).

In selecting specimens for analysis great pains were taken to avoid getting either a too high or a too low average. Two or three tons of the fragments thrown down from the breast of limestone in the quarries Nos. 1 and 5 were in each case mixed and divided, so that the one hundred pounds finally boxed up for analysis was a fair sample of the entire lot. These boxes of samples were nailed up and secured under the eye of the author, and by him shipped to his

laboratory in Philadelphia from the railway depot in New Windsor. The zinc blende was principally obtained from No. 5, because it is best exposed in that cut, yet there is no doubt of the existence of this mineral in No. 6.

The following analyses are fair types of a much larger number of determinations made. The copper analysis selected was of that ore out of the whole number, in which the percentage of copper was the lowest.

No. 1, dark ore from contact ferruginous belt in quarry No. 1.

No. 2, light blue ore from No. 1.

No. 3, zinc ore from No. 5 (lies 10 to 15 feet below the contact belt).

	1	2	3
*Specific gravity,	3.53	2.901	——
	Per cent.	Per cent.	Per cent.
Insoluble residue,	8.97	0.87	88.06
Carbon dioxide,		44.44	
Alumina,	24.21	4.55	
Iron sesquioxide,		0.51	
Lime,		23.84	
Magnesia,		8.94	
Copper,	23.70	12.90	
Lead,	trace	trace	
Arsenic,		none	
Sulphur,		1.90	
Water,		2.70	
Zinc sulphide,			40.98
Iron pyrites,			1.07
		100 15	

To apply these facts to the estimation of the value of this ore:

The length of the outcrops of the copper ore across Mr. Roop's tract is about thirteen hundred feet. The length of the curve of the ore under ground is about fourteen hundred feet. The minimum thickness of the copper-bearing rock is five feet.

Assuming the lowest of the specific gravities given above (viz., 2.9) there would be 1300 ft. × 1400 ft. × 5 ft. × 62.39 lbs.† × 2.9 sp. gr. = 700,030 tons (of 2352 pounds) of copper ore on this property. The lowest percentage of copper yielded by any of the ores which were analyzed, was 12.9. Assuming nearly 1 per cent. lower than this, or 12 per cent. for the average of the ore, the por-

* Determined from fragment, not from powder.

† Weight of cubic foot of water.

tion of this copper ore basin contained on Mr. Roop's farm would produce 84,004* tons (of 2352 pounds) or 98,789 tons (of 2000 pounds) of ingots.

The facilities of transportation are much better from the Roop farm than from the Liberty Mines, as the Western Maryland (but little over a mile distant), and the Columbia and Frederick railroads place it in communication with all points West, East, North and South.

It may be added that the farm is situated in one of the most fertile parts of Maryland, and is worth, for farming purposes alone (as the writer is informed by the persons who live there), from $100 to $150 per acre.

The property is near a water divide, but it is said that any amount of water required for mining can be obtained by wells.

The extent and value of the zinc, lead, and manganese deposits have not been satisfactorily ascertained, on account of the meagre exploration, but it seems quite safe to assert that the former, and perhaps the latter, of these metals exists in quantities large enough to increase the sum total of mineral wealth in the ground.

The proximity of the place to the great centres of trade, and especially to Baltimore, will greatly simplify the problem of utilizing the ores, which may be loaded cheaply, and sent to any of the copper works of Baltimore or Philadelphia, or the seaboard.

April, 1879.

The following memoranda were made from verbal statements by Mr. Hutchinson:

Since April, 1879, a 50-foot shaft has been sunk on the line of strike between openings Nos. 1 and 3, and good ore was struck. It was called "New No. 1." The width of the "vein" (*sic*) here is about six feet at a depth of fifty feet. Samples were taken from "New No. 1" (which is about twenty-five feet southwest of Old No. 1) in December, 1879, and analyzed by Booth & Garrett. They were of two kinds: 1st. Unwashed, or just as they lay on the dump. 2d. Washed and cleaned from adhering impurities.

* Mr. Daniel King, who is familiar with this region, reports having found a piece, selected haphazard from the dump of hole No. 1, as low as 7 per cent. in copper. Taking this, the number of tons of ingot represented by the ore, would be 49.002 tons. It may be mentioned, in passing, that Mr. King agrees entirely with the author as to the structure and all other elements of the calculation of quantity.

The first specimens analyzed 36.92 per cent. copper.

The second specimens analyzed 44.92 per cent. copper.

A mass of ore weighing about three hundred pounds was knocked out of the "New No. 1," and was broken into fragments of about twenty-five pounds. They were full of "gray copper."

On December 21st, 1879, Mr. Hutchinson picked up some pieces of rock which were being thrown away as waste. By analysis of Booth & Garrett they contained 7.77 per cent. copper. The dirt around them assayed 9.38 per cent.

February 24th, 1880, the average output of this hole was ore containing 22.61 per cent. copper (gray copper).

454 pounds of this ore was sent to Pope, Cole & Co., who paid for it as ore of "28.10 Cu.; water, 0."

Opening No. 3 has been sunk down about ten feet deeper, and shows the same vein as rich as No. 1.

Mr. Hutchinson authorizes the statement, 1st, that the ore grows richer as depth is gained; 2d, the width increases so far as data can be obtained. A fair average of the paying zone is not less than six feet.

NOTE.—The following letter was recently received from Mr. Hutchinson in answer to one asking information as to the changes since the date of my visit.

October 8th, 1880.

PROFESSOR PERSIFOR FRAZER.

DEAR SIR: In reply to your inquiries in reference to the Roop Farm operations, I would say:

1st. There has been one new opening made about one hundred and fifty feet from the one designated on your map as No. 1, where they went down about forty-five feet from the surface. It was commenced some time in December last, and work suspended about the middle of March, 1880.

2d. No work of any account has been done on the old openings.

3d. The theory of structure as far as gone agrees with the developments *perfectly*.

4th. The assays are as follows: December 12th, 1879, by Messrs Booth, Garrett & Blair, of this city, two samples: Washed, 44.92 per cent. copper; unwashed, 36.92 per cent. copper.

These were nuggets from surface of new opening, taken from the dumps without selection.

December 31st, 1879, by same: Rock, low grade, 7.77 per cent. copper; dirt, 9.38 per cent. copper; from north side of opening, six feet from surface.

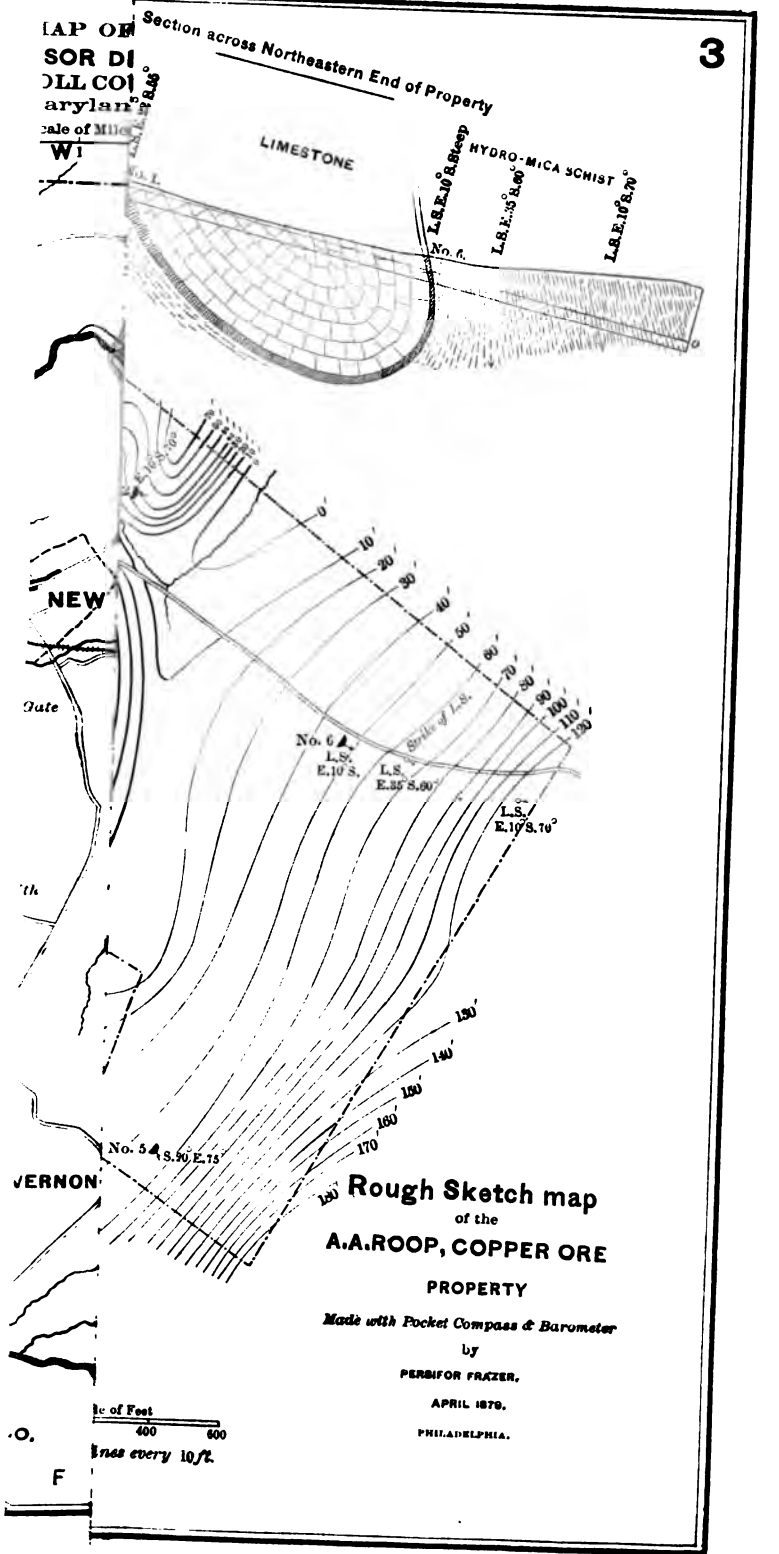
February 24th, 1880: From sample of ground ore, metallic copper, 22.61 per cent., taken from about thirty-five to forty feet from the surface.

February 20th, 1880, by Pope, Cole & Co., Baltimore: Barrel of cobbed ore, 23.10 per cent., nearly all surface ore.

5th. But small quantity sold, for which was paid $3.00 per unit.

Very respectfully yours,

E. HUTCHINSON.


3
Section across Northeastern End of Property
LIMESTONE
HYDRO-MICA SCHIST
L.S. E.10° S. Steep
L.S. E.35° S.60°
L.S. E.10° S.70°
No. 6.
No. 6
L.S. E.10° S.
L.S. E.35° S.60°
L.S. E.10° S.70°
Strike of L.S.
0'
10'
20'
30'
40'
50'
60'
70'
80'
90'
100'
110'
120'
130'
140'
150'
160'
170'
180'
No. 5
S.50° E.75°
NEW
Gate
VERNON
Rough Sketch map
of the
A.A.ROOP, COPPER ORE
PROPERTY
Made with Pocket Compass & Barometer
by
PERSIFOR FRAZER.
APRIL 1879.
PHILADELPHIA.
le of Feet
400
600
lines every 10 ft.

NOTES ON TWO SCAFFOLDS AT THE CEDAR POINT FURNACE.

BY T. F. WITHERBEE, PORT HENRY, N. Y.

On the 22d of November, 1879, white iron unexpectedly appeared while working the Cedar Point Furnace, Port Henry, N. Y., on the following burden, calculated to turn out mill and foundry iron:

Anthracite coal,	3000 pounds.
Connellsville coke,	1500 "
Total,	4500 "
Old Bed ore,	3750 "
New Bed fine ore,	2000 "
New Bed chunk ore,	1000 "
Kearney hematite ore,	750 "
Total,	7500 "
Magnesian limestone,	1665 "
Common limestone,	835 "
Total,	2500 "

The production per week since making mill iron—from September 1st, 1879, to date, seven weeks—was 412 gross tons. Ore was not immediately taken off, as nothing serious was looked for. The iron for the next week graded from No. 4 to white, and in six days the make was 274½ tons. At 10 P.M., Friday, the 28th, a slip of 14 feet occurred, and on Saturday, at 5 A.M., another of 3 feet on the south side and 7 feet on the north side took place. At this time it was found that the south side had been hanging for over a week—a fact which had not been reported. Throwing off the wind, to produce slips and reduce pressure, had been tried with no effect. The stock, as seen through the tuyeres, seemed to consist almost entirely of coal, with just enough infusible cinder to cement it into a mass through which the blast could not be forced. At 3.50 A.M., Sunday, the 30th, the first cinder seen in seventeen hours came into tuyeres Nos. 1, 2, 3, and 6. At 9.30 A.M. No. 3 was taken out to see if the stock

could be "heaved out" by hard blowing, and such help as could be given with bars. Two hours' work showed that no benefit could be had in that way, and at 11.30 the tuyere was put back. The pressure was found to have gone down from 15 to 4½ pounds, with two more turns of the engine, accompanied by a big rush of gas, which had entirely ceased for twelve hours. The trifling amount of stock blown out was mostly lime and coal, and a little brown spongy cinder, too infusible to run. At 3.30 P.M. another slip of 18 feet occurred after the furnace had been hanging thirty-four and a half hours. This brought the pressure up again to 6½ pounds, and from that point it gradually went higher, and the gas failed, so that, for the second time, it was all given to the stoves. Forty-four barrows of coke were put in immediately after the slip on the north side, thus levelling up the stock at 20 feet from the tunnel head.

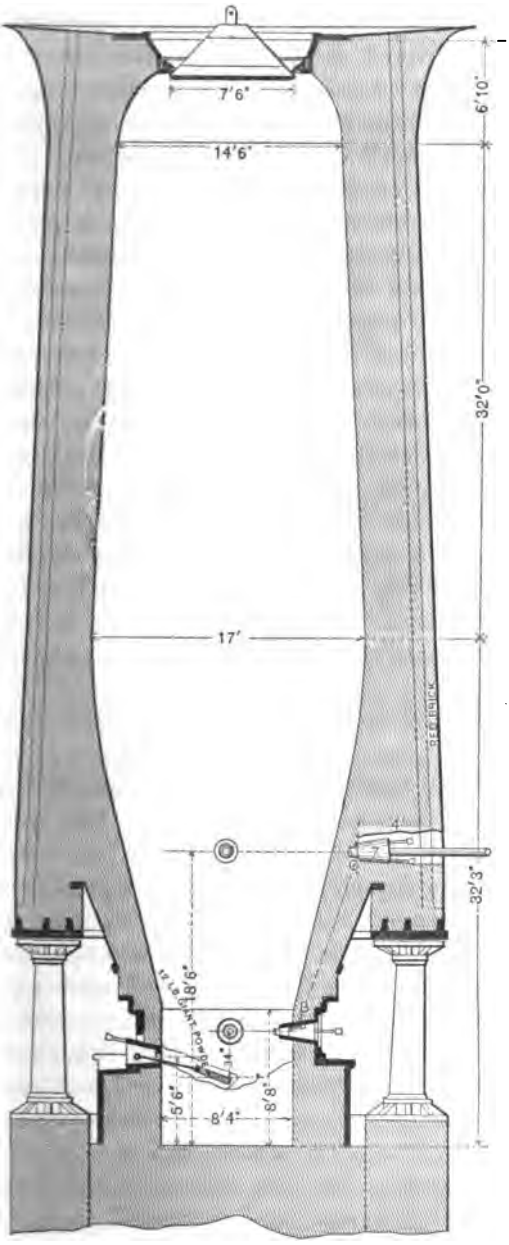
Six beds of white iron were cast at 4.30 P.M. on seven tubs of cinder, which was tough, stringy, and of a dark-brown color. The same kind of cinder slowly flowed through the Lürmann cinder notch from 7 P.M., and by 11 A.M. Monday, things had considerably improved. The pressure, however, kept up very high, seven to eight turns of the engine giving 14 to 17 pounds per square inch. The tuyeres had brightened up, and live stock, coal, and coke showed in front of them. At 12 M. the engine came up to ten turns. The stoves had maintained very good blast heat, although the gas had stopped entirely at times—in one instance for twelve and in another for fourteen hours. Five beds of white iron were cast at 2 P.M., and the furnace slipped over 20 feet, which filled the crucible with gummy cinder and stock so that no wind could enter. The tuyeres were cleaned out and the engine kept going by main force. The furnace, as before, was filled up to within 20 feet of the top with forty-eight barrows of coke, and, in addition, 4000 pounds of cinder were put on.

A council of war decided that the game was up, no one having any remedy to suggest. Kerosene had been tried on two previous occasions, with the only result of lending the works its characteristic perfume for the next six months.

Finally, it was decided to try the effect of a tuyere above the mantel, and one was put in as shown in the drawing, 18 feet 6 inches above the bottom. The brickwork was much thicker at that point than was expected, showing only about 1 foot wear in two years. The bronze tuyere shown in the drawing came just flush with the inside of the lining. As will be seen, it pitched down, a

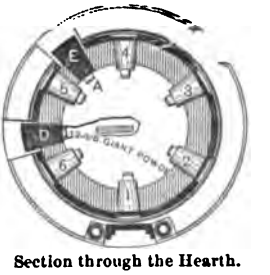
circumstance which was not specially intended. The appearance of the materials at this point was waited for with some curiosity, as it

FIG. 1.



Vertical Section of Cedar Point Furnace.

FIG. 2.



Section through the Hearth.

FIG. 3.

Front View of Cinder Arch.

is seldom the fortune, or misfortune, of one to get an inside view so high in the boshes. The brickwork was found to be but little burned, being white nearly to the end. Then came about 2½ feet of dust, which sparkled and glowed when exposed to the air, showing it to be in part carbon. It was packed so hard that a bar was with difficulty driven through it to snuff the tuyere. It took about six hours to connect wind-pipes and set the tuyere, during which time the wind was off the furnace. When all was ready, the lower tuyeres were snuffed out as well as possible, and the wind put on. The pressure had gone down to 1½ pounds with 8½ turns of the engine. In one hour another slip of an unknown distance occurred, but, judging by the concussion, it was fully equal to any of the others. The high tuyere melted very fast, and did good execution on something, but whether the whole or any part of the relief came from it, or whether it was due to standing still during the six hours mentioned, is hard to tell. Still, the only thing that throws doubt on the efficacy of the tuyere is the change coming so soon after it was put at work. The low pressure observed immediately after the stop may have been caused by the passage of all of the wind through the high (No. 7) tuyere. It was evidently located below the scaffold. Perhaps the most singular feature about this case is the fact that neither the iron nor cinder notches were lost during the whole time. The whole distance slipped amounted to at least 47 feet in the four days, and the time during which no movement of the stock was known was fifty-seven hours.

From this time the furnace was treated as though it had been blown out, and was filled up again with 2100-pound charges of ore as a commencement, rapidly increasing until 7200 pounds was reached, which took until December 9th, six days. The week ending December 13th showed 429½ tons, and the next four, 438½, 448, 442, and 469 tons. On January 8th, 1880, the burden was increased, as No. 1 iron was made when mill iron was wanted. A change was again made January 13th by an error in setting the scales, by which 330 pounds of ore and 125 pounds of stone were added to a charge already too heavy. The mistake was not discovered for three days, and then there remained some three days more to get rid of that in the stack. The furnace was in such good condition that the error was merely corrected, and no change of any great amount was made from the usual burden, as it was thought that by blowing light and keeping the blast well up things would ultimately right themselves. Although the iron tended to be too

hard in quality, a fair amount was made. During the week ending January 17th the product was 389 tons, and for those following 384½, 402½, 433, and 366 tons. During this time, ending February 14th, many slips occurred, but none of any great distance.

The coke was increased to one-half and to various lesser amounts, to see if it would not make things run more smoothly, but with no good results. On February 10th we began to gradually diminish the amount of coke, as notice was received that shipments were stopped on account of a strike, and by the 13th all coke was taken off. On Sunday, February 15th, the coke in the crucible was down to 10 per cent., or 450 pounds. At 11 A.M. nine beds of mottled iron were cast, and cinder of good quality was obtained at 1 P.M. The pressure had been up pretty high during the preceding night, and the wind was thrown off several times to reduce it. At 1.30 P.M. the cinder suddenly stopped and the wind blew hard through the cinder tap with a peculiar bellowing sound, indicating a hollowness inside. The wind was again cut off to relieve the 10-pound pressure. No movement was noticed until the wind went on, and then a 4-foot slip occurred, filling every tuyere with mushy cinder, which partly blew out again. No coal was in sight at the tuyeres, but a frothy red cinder appeared, looking like a red-hot sponge, owing to the holes made through it by the blast, and in it black chunks of lime were tumbling around. The pressure at this time was 11 pounds with seven turns of the engine. A cast was made right away in order to relieve the tuyeres, four beds of iron and a small amount of cinder being obtained. As serious trouble was indicated, all gas was turned to the stoves, one being held in reserve, and worked up hot to be used when it would do most good. At 8 P.M. no improvement had taken place, the tuyeres closing up as fast as they were opened. The gas was failing, steam was low, and not much wind was going into furnace; 1½ beds of iron and a trifling amount of cinder were cast. On Monday, the 16th, at 7 A.M., it was decided to take out the south cinder arch, in order to get a big hole to enable us to heave out again. It was found a hard job to dig it out, and so it was decided to try to blow it out with giant powder, a charge of which was placed just inside of the arch through the hole where the cinder tuyere goes (see A on drawing). One cartridge of half a pound just shook it up and enlarged the hole. Next four cartridges were put in, which blew the arch and cinder spouts out into the yard, caused a 3-foot slip, and brought out at least twenty cartloads of mushy cinder, full of coal-dust and lime. The gas started

immediately, and the pressure dropped down to 6 pounds. Holes were got through the tuyere breasts to No. 2 and 4 tuyeres, and some cinder was taken out. The improvement did not, however, last long, the gas died out, and the pressure again went up. On this day wind was put through the high (No. 7) tuyere. At this point the stock was simply a gummy mass about 3 feet thick. The wind did not do much through this tuyere, and, by mistake, it was shut off and filled up with cinder. At 8 A.M., on the 17th, it was decided to blow out the north cinder arch. Three cartridges were put in, which just brought it out, with no further benefit.

The salamander was found to rest on a bed of anthracite coal about even with the bottom of the cinder arch, as shown in the drawing. One of the helpers was set to digging a hole just under the salamander, which he succeeded in doing without much difficulty by working out the lumps of coal clear to the centre of the crucible and dipping down about 34 inches below the tuyeres (see drawing). Into this a charge of 12 pounds, equal to 22 cartridges of "giant" and "Monaky" powder, went at 2 P M.

This cartridge was made by removing the paper from the common cartridge and ramming the loose powder into a box 5 x 6 x 27 inches, made of ½-inch pine, to which was fastened an iron handle. Two exploders were put in it, with two lines of fuse, the outer ends being wound close together and cut off square, so that both could be fired simultaneously. The hole was very hot and contained a few quarts of melted iron at the bottom. Cooling off with water would not do, as the "Monaky" powder would explode in boiling water, so a trial was made with wet clay, with which the hole was filled, and then a hard wood scantling 6 x 8 inches was driven in and removed to make room for the box. The clay could not be made to stick on to the top of the hole, and would not entirely cover the iron in the bottom, and as matters were getting worse all the time it was decided to make the attempt. By means of the handle the box was thrust to the bottom of the hole and the fuses fired by a hot iron, while an assistant, Mr. Duffy, with a hoe, packed sand in the mouth of the hole. Probably less than ten seconds was used in loading, tamping, firing, and fleeing from the wrath to come.

Some had predicted, as the result, damage ranging from total destruction of the stack down to a mere fizzle. So, for want of better occupation, the upper part of the stack was watched with considerable interest. The explosion was not very loud, and no movement of the stack visible to the eye took place, although the

ground shook considerably, seemingly before the noise was heard. The wind was on the furnace at the time, but probably little or none going in, and upon getting back to the stack it was plain that things had changed. Gas was coming out around every tuyere and through all the joints of the casing, from the tuyere breasts down, and for one-half the way around the stack there was an accumulation of mushy cinder and lime, with an occasional rounded lump of small coal, from 1 to 2 feet thick, the total quantity being about fifty cartloads. The stock had gone down an unknown distance, and the salamander about as far up, and good coal appeared in front of No. 6 and No. 2 tuyeres for the first time in forty-eight hours. The damage was confined to the breaking off of two ¾-inch water-pipes and of one lug of No. 6 tuyere pipe. The engine was stopped, and No. 2 and No. 6 tuyeres cleaned out and put at work, with wind from the stove in reserve at 1700 degrees. The north cinder arch, in which the explosion was made, gave an outlet for cinder, and also several holes drilled through the brickwork between Nos. 1 and 2 and Nos. 2 and 3 tuyeres. Plenty of gas came through and melting began at once, the pressure being 5 pounds. Cinder and iron soon began to flow, and a general improvement took place until 10 P.M., when the drilled holes began to clog, so that the cinder arch had to be opened in order to heave out again, as had been done at 6 P.M. previously. In two hours an immense amount of material had been blown out, and No. 6 tuyere was in good shape. No. 2 was full of cinder, occasioned by stopping to close up the cinder arch. That was taken down and cleaned (with the wind on No. 6), and blast put on it. From midnight until morning No. 5 opened itself, and cinder broke out of the south cinder arch. At 7 A.M., 18th, No. 1 tuyere was opened, and at 2 P.M., No. 3. Five tuyeres were now at work. The back one—No. 4—was allowed to remain closed several days, as the stock settled fastest over that tuyere. The furnace was again treated as blown out and filled as before, and has worked very smoothly up to the present time.

It will be noticed that, in the first case, the material in the crucible was nearly all coal, with nothing to melt with it, and, in the second, cinder and lime, and no coal to melt it.

Giant powder has been used in one other instance. Three months ago the brickwork became entirely removed from behind the iron dam plates, so that iron could not be kept in, and of course the iron and cinder came forward and chilled on the front. The dam plates were taken down, and, by means of shallow holes from 6 to 10

inches deep, a "drift" was driven into the front the whole surface of the dam, so that one course of bricks could be laid. The holes were much above a red heat, and one shot in the bottom tapped out iron. Twenty-six shots were required, using from ¼ to ½ pound giant powder each. In this instance pine cartridge cases were used, made by boring out holes in pine plugs. In some cases the wood was not over $\frac{1}{16}$th of an inch thick, and no clay was used. Generally the fuses were fired before the cartridges were put in the holes, —much the safest plan,—while the tamping consisted of a shovelful of sand thrown against the hole.

In conclusion, whatever doubt may exist as to the benefit derived from the high tuyere, none need be felt about the effect of the explosion, as that and nothing else did or could have saved the furnace. The boshes and crucibles are known to have been cut, as shown by dotted line B C, for at least eighteen months.

A COMPARISON OF CERTAIN FORMS OF PORTS FOR STEEL-MELTING FURNACES.

BY P. BARNES, SPRINGFIELD, ILLINOIS.

THE object of this paper is to make a brief comparison of the outlines of several forms of ports for steel-melting furnaces, in reference chiefly to the proper mixture of the gas and air, and to the direction in which the flame is thrown down into the interior of the furnace.

In the illustrations on the accompanying plate, Fig. 1 shows a form of port designed by M. Pernot, of St. Chamond, France. This is used with the dome roof preferred by him for the revolving bottom that bears his name. From No. 1 has been derived No. 2. This is shown on the plans of Mr. A. L. Holley, and from them three large furnaces have been built and put into operation by the Springfield Iron Company. Fig. 3 shows an outline proposed by Messrs. Richmond & Potts for the Pernot furnace. In this the ports are brought in under an arched roof of nearly the ordinary form, instead of over the top of the roof, as with the dome of M. Pernot. Fig. 4 shows a furnace as built by Krupp, of Essen, Prussia, for fluid refining, or "washing"—to use the briefer French term. In this the gas and air come into contact in broad sheets, one above the other. Fig. 5 shows the form used by Messrs. Richmond & Potts

in recent drawings for a furnace with a fixed bottom. Fig. 6 shows a plan of Mr. S. T. Wellman, of Cleveland, Ohio, for a similar fixed furnace.

These outlines are all taken from plans prepared for actual construction, and, though they may not be absolutely like any given furnace, they nevertheless represent accurately the different views of men of experience and good judgment. The outline of the porthole in Fig. 2, in the dome roof, has been made more nearly a semicircle, but in other respects Fig. 2 shows the arrangement now in actual use.

In general terms the office of these ports may be stated to be, (1), to lead the gas and air to the point or place of actual contact or mixture; (2), to cause their intimate mixture, and hence their complete combustion; (3), to direct the resulting column, or body of flame, downward at the most effective angle on to the bed, or the contents of the furnace; and (4) (secondarily), to lead away the waste gas, and thus by absorption of the waste heat, to aid in regeneration at each reversing. Of these points only 2 and 3 call for special consideration in this paper.

It is probable that this complete and intimate mixture is more fully promoted by causing the streams of air and gas to strike each other forcibly, as in Fig. 2, than by the more quiet diffusion of their currents, as in Fig. 3; and the difference between Figs. 2 and 3, in this respect, is remarkable. It is certain that they must strike each other from the sharp convergence of the horizontal portways through which they pass, and the needful velocity may always be derived from the gas cooling-tube leading from the producers, and also from the simple draft of air upward through the hot regenerator. The inclosed, though ample space, in which the mixture actually occurs, insures a complete whirl or reverberation, which, in all furnaces, is so effective a means of promoting combustion. By the inclosing port-walls the combined jet, or column of flame, is thrown almost vertically down on the bath of metal, or on to the bottom of the furnace, before the metal is charged. This necessity of giving a sharp downward pitch to the flame has been more fully recognized of late years than formerly; and, to those familiar with the subject, the difference between Fig. 5 and the earlier forms of roof for a fixed furnace in this respect will be very apparent. From the actual use of one of the Pernot furnaces, as shown in Fig. 2, for a considerable time by the Springfield Iron Company, it would seem that there is but little remaining to be desired in its working in respect to items 2 and 3.

keeping the furnace completely filled with gas, so long as an effective head is maintained at the producers, and the regulating valves and damper are skilfully handled. It is true that the furnaces, of which parts are shown, are not all exactly of the same size, but they are nearly so, and all are of large capacity, Figs. 1 and 2 being fully equal to melting eighteen to twenty tons at one heat. Hence the details shown may be very properly taken as comparable with each other, and also as worthy of careful study for economy's sake.

It is hardly needful to say that the considerations thus advanced are probably identical with those upon which this form of construction was reasoned out and developed by M. Pernot some four or five years ago. It is true, however, that comparative criticism, even of useful and successful details of construction, may often lead to further improvement by a statement of the principles involved and the steps traced in their development. The interest of the Springfield Iron Company in a critical examination of such details may be inferred from the fact that they have in actual use, for heating and melting, fourteen gas furnaces (nine being of the largest size) and forty-eight gas producers. Theirs is one of the largest plants of this kind of gas apparatus in the country at the present time.

A SHORT BLAST AT THE WARWICK FURNACE, PENNSYLVANIA.

BY JOHN BIRKINBINE, PHILADELPHIA.

FOR two years past the Warwick Furnace, at Pottstown, Pa., has attracted attention by the remarkable work done in it, and a statement giving details of its operation and the unexpectedly short blast of 1880 will be acceptable to every member who studies blast-furnace practice. There are so many interesting features in connection with this blast, and so much to be learned from investigating it, that the results of a thorough examination are offered to the Institute *sans théories*. In collecting the information, the courtesy of the various officers of the Warwick Iron Company was of material advantage, every facility for investigation being extended and an inspection of records being kindly permitted.

In the following description these authoritative data are given in full where practicable, without making the paper too prolix, and the

writer acknowledges his indebtedness to the manager for information supplied, and only claims for himself the collection and arrangements of the facts so as to be of service, together with personal observations verifying the same as far as could be done after the furnace had been emptied:

The furnace was built in 1875–76, and first blown-in in April, 1876. Prior to 1878 no extraordinary product was made from it, the best week's work being 189.5 gross tons. The stack is 16 feet bosh and 55 feet high, constructed of brick banded with iron. Blast is supplied by a vertical noncondensing engine, with air cylinder 96 inches diameter; steam cylinder, 48 inches diameter and 7 feet stroke, and heated in two iron-pipe hot ovens, one with 24 the other with 20 ∩ pipes, the aggregate heating surface being 3600 square feet. Steam is generated in six cylindrical boilers, 48 inches in diameter and 70 feet long, and one tubular boiler. The furnace is blown with six tuyeres.

In the latter part of 1877 the furnace was remodelled from plans furnished by Mr. P. L. Weimer, engineer, and placed under the management of Mr. Edgar S. Cook. No changes were made in the features of the plant except the stack, the engine, hot blast, boilers, etc., remaining as before. The proportions of the stack (or lines) were arranged to suit the requirements of the furnace, which makes mill iron a specialty, and adapted to the ores to be used. On December 29th, 1877, the furnace was blown-in, and the blast continued for 105 weeks, during which time 37,400 tons (2268 pounds) of pig iron were made, an average of 356.2 tons per week. The consumption of coal for the blast (anthracite only being used) averaged 1.2875 tons (2240 pounds) per ton of iron, including the filling of the furnace. The ores used averaged 45.9 per cent., and 0.6875 gross tons of limestone were required per ton of pig iron. During this blast the monthly maxima and minima were:

Tons of pig iron made, ...	1728 5	1143.5
Tons of anthracite per ton of iron, . . .	1.375	1.2125
Yield of ore in furnace, per cent., . . .	47.4	42.5

The record of this blast exhibits a remarkable uniformity in all the operations up to the last, when the furnace was forced to blow out, as the lining had so worn away that part of the backing fell in. The full, irregular lines on Fig. 1 on the accompanying plate exhibit the shape of the furnace at the close of this blast.

The operation of the plant had been so satisfactory that the stack

was relined to the same shape as before, which is shown on Fig. 1 by the straight dotted lines. The principal dimensions were as follows:

	Feet.	Inches.
Diameter of crucible,	7	5
Height of crucible,	8	6
Diameter of bosh,	16	0
Height of bosh from bottom,	21	6
Diameter at stock line,	10	0
Diameter of bell,	7	0
Total height of furnace,	55	4

Six tuyeres—centres 5 feet from bottom.

On March 27th, 1880, the furnace was again blown-in and continued to work uniformly and regularly up to June 4th, 1880, when it went out of blast under such peculiar circumstances that a recital of its working and a description of its stoppage in detail will doubtless present many facts of interest to blast-furnace managers. During this short blast—less than ten weeks—3777½ gross tons of pig iron were made.

To permit of a better understanding of the details of operation, the following synopsis of the working of the furnace is given: It

RECORD OF WARWICK FURNACE BLAST OF 1880.

Weeks.	Revolutions per minute.	Cubic feet of air per minute.	Pressure in pounds.	Cubic feet of air per ton of iron.	Cubic feet of air per pound of coal.	Gross tons of coal per ton of iron.	Yield of ore, per cent.	GROSS TONS OF IRON MADE. No. 1, F.	No. 2, F.	No. 2, M.	No. 3, M.	G. M.	Total.	Temperature of blast, degrees. F	Temp. gas at tunnel head, degrees. F	Charges.	Stops in minutes.	Per cent. of coal to ore.
1st.*								219½	50				269½					50.1
2d.	12.5	8796.2	7.9	232,713	74.5	1.375	43.48	247½	117				364½	774		562	437	58.8
3d.	12.7	8937	8.3	238,183	78.	1.3625	43.20	34½	186½	135			356	757		543	593	54.7
4th.	12.	8444.6	8.7	211,503	74.5	1.2625	43.20		155½	72½	152½		380½	770	413	540	550	55.3
5th.	12.	8444.6	7.1	192,974	69.6	1.2375	44.70		14	135½	275½		425	827	327	589	368	57.1
6th.	12.	8444.6	7.4	197,789	71.0	1.2375	46.00			15	378½	16½	410	800	340	571	477	56.4
7th.	12.	8444.6	8.3	207,419	74.1	1.2500	45.15			117	276		393	815	363	550	427	54.5
8th.	12	8444.6	8.3	201,200	74.5	1.2000	45.15			27½	342½	36½	406½	840	357	549	395	56.3
9th.	12.	8444.6	7.4	198,041	72.3	1.225	45.90				358½	54	412½	850	401	564	418	55.9
10th.†	12.	8444.6	7.7	200,432	71.9	1.2500	44.90			41½	249		290½	845	350	405	305	
Friday, June 4, 1880										8	52		60					
Last cast made												9½	9½					
Total								501½	523	552½	2084½	116½	3777½					

* First six days. † First five days of the week.

will be noticed that the average revolutions of the engine and the pressure of blast varies within narrow limits, and that the coal per ton of iron is very uniform, and is remarkably low, considering the yield of the ores. The consumption of air per ton of iron and per

pound of fuel remains nearly constant. (In each case the amount of air is calculated from the number of revolutions of engine per minute, less stoppages, no other deductions being made.) No white iron was made; after the first three weeks the furnace was maintained on its specialty, mill iron. The temperature of the gas at the tunnel head was low and the charges settled regularly. All these facts lead to the conclusion that the furnace operated with great uniformity, that the large yield was not necessarily obtained by undue forcing, and that the sudden stoppage cannot be accounted for by the record of the working of the furnace.

The method of calculating the cubic feet of air from the average revolutions is, of necessity, not exact. The iron is graded as No. 1 and No. 2 foundry, No. 2 and No. 3 mill, gray mottled, white mottled, and white. The percentage of coal to ore represents the pounds of fuel consumed for each 100 pounds of ore smelted.

The first week is omitted from the table except as to the iron made, as no details could be worked out, owing to the filling of the furnace and to the time occupied—six days. For similar reasons the last day of blast, being incomplete, is not included in the details, the figures being worked up for the five days only.

As a means of throwing more light upon the subject of the behavior of the furnace, some analyses of cinder are given. These

ANALYSES OF CINDER AT WARWICK FURNACE.

	Silica.	Alumina.	Lime.	Magnesia.
First flush of cinder in blast, March 28, 1880	35.0	23.0	35.8	7.3
Average of 2d, 3d, 4th, and 5th flushes of blast, March 28, 1880	37.0	20.5	36.7	7.5
Average of all flushes, A.M., March 29, 1880	37.5	18.0	36.6	8.3
*Average of all flushes, P.M., March 29, 1880	39.0	16.5	35.5	9.7
Average of all flushes, March 31, 1880	35.5	14 0	39.4	10.8
Average of all flushes, April 15, 1880	36.5	17.5	38.0	7.0
Average of all flushes, A.M., April 19, 1880	38.5	14.0	36.6	8.9
Average of all flushes, P.M., April 19, 1880	36.5	16.0	37.8	8.7
Average of all flushes, May 1, 1880	35.5	17.0	37.5	8.6
Average of all flushes, May 18, 1880	36.5	15 0	40.3	7.2
Average of all flushes, June 1, 1880	37.0	14.5	41.8	6.4
†Average of cinder made during May and up to June 4, 1880, including last flush made in blast	35.0	15.0	39.1	11.4

* Different mixtures of ores working A.M. and P.M.

† This analysis was made from samples of the various flushes, taken by direction of the manager and retained.

The iron was not separated from the alumina in the analyses, there being but a trace present.

show a uniformly well-fluxed cinder, and an inspection of the dump bank verifies the analyses, and shows little or no change in physical character. The composition is such as would not encourage the

belief that they would severely scour and rapidly destroy the fire-brick lining; nor that they would cause any impediment to continuous, regular work. As will be seen by the extracts which follow, the cinder remained quite constant in character up to and including the last flush run.

As this description would be incomplete without some mention of the ores used, the following analyses are given. They are approximate averages taken from a large number of each ore. During the blast a variety of mixtures were used, but an average was:

30 per cent. Boyertown magnetic, roasted, . . Analysis A
10 per cent. Cornwall magnetic, ... Analysis B
20 per cent. Flourtown hematite, } 2 varieties, . { Analysis C
10 per cent. Flourtown hematite, } { Analysis D
10 per cent. Lancaster County hematite, . . . Analysis E
10 per cent. Siesholtzville magnetic, ... Analysis F
10 per cent. puddle cinder, ... Analysis G

	A	B	C	D	E	F	G
Silica	15.5	15.0	24 0	13 0	26.5	11.0	21.0
Alumina	8.0	4.0	4.5	3.5	11.0	6.0	6.0
Lime	10 5	3.5	0.5	0.5	1.4	14.6	1.0
Magnesia	4 7	5.5	1 0	1.0	1.8	6.8	1.5
Metallic iron	43.0	48.0	42 0	45.0	35.7	30.0	55.0
Phosphorus	0.1	.....	0 3	0.3	0.15	0.08	1.5
Sulphur	2.0	3.5	.....	.....	.....	.....	.....
Manganese	.....	.....	.....	.....	.....	1.8	.....

The furnace was given charges based on 2000 pounds of coal. Anthracite coal only was used, of "steamboat" size, no coke or other fuel being at any time charged into the furnace. The burden of ore ranged from 3200 to 3700 pounds, the average percentage of limestone to ore being 35.

To describe the operation of the furnace and its behavior at the close of the blast, the following extracts from the furnace diary, made by permission of Mr. Cook, are given *verbatim*. As these records were made several times a day, they give a statement of the circumstances existing at the time of making the entries. The entries preceding those given were of similar character:

"Sunday, May 30th, A.M.—Revolutions, 12; pressure at furnace, 7 to 7½ pounds; blast, 800 to 850 degrees; cinder, fair gray, hot, and fluid; gas gray, burns hot, and good; stock settles even and regular; pressure regular; filled 41 charges.

"Sunday, P.M.—Revolutions, 12; pressure, 7½ pounds, regular; blast, 850 degrees; cinder, fair gray, hot, and liquid; gas unchanged; stock settles regular and even; filled 40 charges; made in 24 hours 58½ tons—14 No. 2, 44½ No. 3.

"Monday, A.M.—Stopped 74 minutes to put in tuyere; revolutions, 12; pressure, 7 to 7½, regular; blast, 800 to 850 degrees; cinder, gray, hot, and fluid; gas good; stock settles even and regular; filled 36 charges.

"Monday, P.M.—Revolutions, 12 to 12½; pressure, 7 to 7½, regular; blast, 850 degrees; cinder and gas unchanged; stock settles even and regular; filled 42 charges; made 55½ tons No. 3; fair gray and strong.

"Tuesday, June 1st, A.M.—Revolutions, 12; pressure, 7½, regular; blast, 850 degrees; cinder sharper; runs hot and liquid; gas good and hot; stock settles even and regular; filled 40 charges.

"Tuesday, P.M.—Pressure 7½ up to midnight, 8½ after midnight; blast, 850 to 800 degrees; cinder sharp; was much grayer toward morning; gas gray and hot; settles even and regular; filled 39 charges; made 59 tons No. 3 iron, fair gray and very strong.

"Wednesday, June 2d, A.M.—Revolutions, 12½; pressure, 8, regular; blast, 850 degrees; cinder, gray, hot, and fluid; gas good and strong; stock settles even and regular; filled 42 charges.

"Wednesday, P.M.—Revolutions, 12½; pressure, 8, regular; blast, 850 degrees; cinder, fair gray, hot, and good; gas gray, plenty, and hot; settles even and regular; filled 42 charges; made 60½ tons No. 3, strong.

"Thursday, June 3d, A.M.—Revolutions, 12½; pressure, 7 to 8; blast, 800 to 850 degrees; cinder good, gray, hot, and fluid; gas gray and hot; stock settled even and regular; filled 40 charges

"Thursday, P.M.—Revolutions, 12; pressure, 7½; after midnight, pressure 9; revolutions, 12½; blast, 800 degrees; cinder, good gray, hot, and fluid; gas gray and good; settles even and regular; filled 43 charges; made 57 tons iron—27½ No. 2, 29½ No. 3."

These quotations from the diary are given at length to exhibit in detail the action of the furnace, which shows no unhealthy condition, but rather presents a more than average regularity. Particular attention is invited to further extracts:

"Friday, June 4th.—Revolutions, 12; pressure varied from 8 to 9; blast, 850 to 900 degrees; cinder sharp, run hot and fluid. From 8 A.M. to 2 P.M. stock settled only with flushes, when the blast was slackened, making pressure irregular; did not make any heavy jumps. After 2 P.M. cast, blast regular; settled no more at than between flushes; stock level on top all day; gas good and abundant. After 2 P.M. cast, cinder was grayer; filled 40 charges.

"Friday, P.M.—After 7 P.M. the pressure suddenly rose from 9 to 12 pounds, with blast on furnace; continued to drive fast and

regularly; no irregular settling; gas abundant, hot, and good gray; did not affect the melting; pressure gradually fell to 9 pounds. Cast at 8 P.M., 14 tons good No. 3 iron; started up all right after cast; revolutions, 12; pressure, 8½ pounds; blast, 850 degrees; settled regularly and evenly; gas abundant and good; cinder well fluxed, fair gray, hot, and fluid. Made 60 tons iron—8 tons No. 2, 52 tons No. 3."

These notes were made from personal observations of the manager, who remained at the furnace until the second flush after cast, about 11.30 P.M. He was called to the furnace again at 2.30 A.M., and the following notes were made from information obtained from the night boss, founder, and top-filler:

"Previous to the third flush after cast (about 1 A.M., Saturday), while the blast was on the furnace, the pressure suddenly rose from 8½ pounds, the engine slackening until it barely passed its centres, the gauge showing 14 pounds pressure; no gas; tuyeres bright; the stock at tunnel-head made no jump; was settling regularly, but while the pressure was increased, it slowly and gradually settled about a foot and then stopped. On flushing, the cinder was fair gray, well fluxed, flowing hot and fluid, clearing the tuyeres perfectly. After closing cinder-notch and starting up again, two tuyeres were found to be closed; no cinder in the pipes, but just at the nose of the tuyeres a semi-liquid or mushy mass stopped the openings. Preparations to cast were at once made; after this flush gas was made for a few minutes and then ceased altogether, the stock at the top making another gentle slide of between one and two feet. There was no jar or sudden movement. By opening an air escape on receivers, the engine was barely kept moving, the pressure by gauge showing 14 pounds. About 2 o'clock 9½ tons mottled iron was run, it and the cinder being hot and fluid. After blowing some minutes, the other four tuyeres were tried and found perfectly free from any signs of cinder. When the engine was stopped these four tuyeres closed at the nose with the same half-fused material as had forced its way into the two first mentioned."

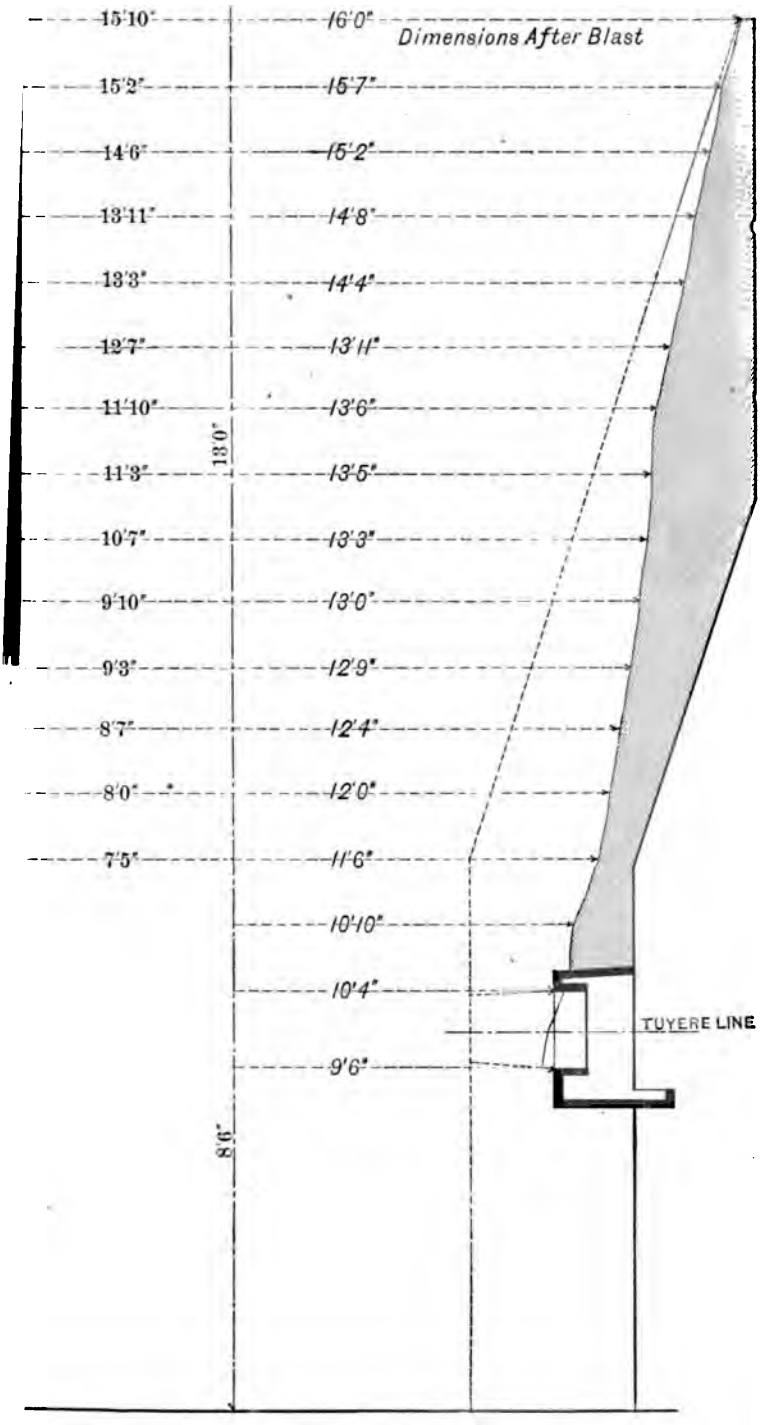
At this time Mr. Cook arrived at the furnace, and the following is the result of his personal observations:

"On removing the caps no cinder whatever was found in the pipes; the nozzles were about 4 inches from the nose of the tuyere, and this space was filled with the half-fused material. On chipping this out it was found to consist of a mixture of fused iron, spongy fire-brick, and some slag. When a tuyere was withdrawn a mass of this material was found, and it appeared to have been scraped

down from the walls of bosh and crucible by the pressure from above and forced into the tuyeres, as described. After the tuyeres were opened the engine was started, but could only be kept moving by opening an escape valve or receiver, as, under a pressure of 14 pounds, it was impossible to force any air through the furnace, although the tuyeres kept open and were bright red. A continuous effort to force blast into the furnace was made during the day with the same result. There were no signs of melting and no gas was made, nor was there any evidence of any blast passing through the furnace. On several occasions a 3-inch bar was forced through each tuyere to the centre of the furnace, and a 1½-inch bar was easily driven from cinder and iron notches to the centre of the furnace and to the opposite walls. Considering any further use of fuel under the boilers useless, the engine was stopped on Saturday evening, June 5th, thus ending the blast, the last 15 hours' blowing having given no results whatever, and the blast having practically ended at 2 A.M.—less than two hours after the first serious indication of trouble, and within 18 hours from the time that the slightest intimation was given of any irregularity of working, which passed away 12 hours before the trouble commenced."

We see from the extracts from the diary that the operation of the furnace during the last six days of the blast was entirely satisfactory, and, with the exception of six hours of slightly varying pressure and settling, there was no possible notice of irregularity of operation. Even had an attempt to alter the burden been made, it would have been of no assistance, as, at the rate the furnace was driving, 28 hours would have been required to effect it. At the time of stopping the burden was 3570 pounds ore to 2000 pounds anthracite, which was about the same as had been carried for the two weeks previous.

On Monday morning work was commenced on cleaning out the furnace. The stack was full to within 5 feet of the stock line. A hole was cut through the brickwork of boshes about 8 feet above the tuyeres, through which the stock in good condition rolled freely, being composed of clean hot coal and limestone, then lumps of ore. When the slope of the stock was such that it did not roll freely, water was sparingly used to wash it down, and yet not injure the brickwork, in hopes that no repairs would be required. When the stock in the well of the crucible was partly removed, an arch was found to have formed across the furnace at the top of the tuyeres which had supported the stock. This arch was composed of dry stock,



NICK FURNACE, BEFORE AND AFTER BLAST.

coal, and limestone in small pieces, and a heavy black powder, evidently reduced ore, was packed very tightly, but yielded to a pick, and extended to a height of over 6 feet above the tuyeres.

No melted or fused material was found anywhere in this bridge, nor was there any chilled iron and slag below the tuyeres. At the level of and around the tuyeres iron was found. When cleaned out the inwalls were found to be in good condition, with no indications of cutting or irregular action. The boshes were found to have been destroyed for 10 feet above the tuyeres, and for the remaining distance partly fused and cindered, being worn as shown on Fig. 1 (dotted lines). The destructive action on the brickwork was noticeable, a black slag-like mass having been formed on the remnants of the blocks, for a depth of from 3 to 5 inches; and it is probable that this was squeezed into the tuyeres. That the lower portion of the boshes wasted away early in the blast is evident from a comparison of the product for the first few weeks with a corresponding time in the former blast, and as the upper portion of the boshes softened, the support for the stock became lessened, until finally all hold was lost, and the material above pressed so heavily that packing and jamming took place above the tuyeres, rendering it impossible to force any blast whatever through the white-hot matted mass. There was no scaffolded material found, nor was there any evidence of any accumulation having existed. Had the furnace worked sectionally, the amount of stock smelted would have been greater than the quantity of fuel which the reduced capacity of the zone of combustion could have consumed; and even if such had not been the case, a scaffold on one side would have protected the walls behind it and worn the other badly; but the measurements taken, as well as the appearance of the boshes, show a remarkable uniformity by the manner in which they cut away, the variations in measurements on the same plane never exceeding 1½ inches, and generally not over 1 inch. The boshes were originally 32 inches thick, made of two 16-inch blocks. When the furnace stopped they were only from 5 to 8 inches for 8 to 10 feet above the tuyeres, the inwalls remaining in good shape and the diameter of the bosh being the same as when blown-in. The bosh was cut away so that work was impossible, and the furnace had worn away in ten weeks to nearly what it had in two years in the former blast; but in this case no holding ground was left for the stock, the walls having been cut to nearer a vertical line than in the first blast. (See Fig. 1.) Fig. 2 illustrates the condition of the furnace before and after the short blast.

*REMOVING SCAFFOLDS IN BLAST FURNACES.**

BY J. P. WITHEROW, PITTSBURGH, PA.

MR. BIRKINBINE'S description of the bad working and sudden chilling of the Warwick Furnace last summer, seems to me quite phenomenal in blast-furnace practice. During my connection with the management of blast furnaces for many years, in the anthracite, coke, and raw-bituminous coal districts, such a case has never come under my notice.

It seems to me that the scaffold in the zone of fusion could not have established itself (so that the whole power of the engines, with a blast pressure ranging from 12 to 18 pounds per square inch, could not penetrate), unless the furnace was previously badly scaffolded and bridged in some of its upper sections, from 15 to 30 feet above the hearth level, either in the zone of chemical action or the beginning of the zone of fusion. Such a barrier to the upward gaseous currents would cause a suspension of combustion which may have superinduced the scaffold that is assumed to have existed in the zone of fusion. It is difficult to conceive that an agglomerated mass almost across the section of the lower bosh should have formed all at once, if the furnace was free and porous for the reaction of the gaseous currents above. Therefore, I think, the Warwick furnace was by no means in as free, open, and fine internal condition at the time the trouble commenced as the description of its regular working would lead us to suppose.

I do not question the accuracy of the statements relative to the output of iron, etc. I merely claim that the phenomena, as described, could not have been almost instantaneously developed, unless there had been an incipient scaffold and lodgment above the zone of fusion. I would state my hypothesis to be that the stock lodged or collected in some of its upper sections during the process of blowing-in, on which, as a basis, more or less accumulations may have lodged, and thus, indirectly, caused the formation of the suc-

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* This paper was not presented to the Institute in its present form, but is based on remarks, in discussion, by the author on Mr. Birkinbine's paper on a Short Blast at the Warwick Furnace, and Mr. Witherbee's paper on Two Scaffolds at the Cedar Point Furnace.

ceeding scaffold, the effects of which have been so graphically described. Furnaces frequently have such lodgments, and when they are local and in the wider areas of the furnace they may not obstruct its working; in fact, they sometimes give no indication of their existence; but when they extend and enlarge by the accumulation of dust, limestone, etc., developing into scaffolds and encircling the upper section of the furnace, the position becomes serious, resulting in a loss of, perhaps, one-third or one-half the working area of that section, and establishing a central channel—a condition which is termed funnelled. Should a heavy fall or slip of accumulated dust, coarse lumps, or masses lodge therein, rendering the same impenetrable to the ascending gases, and causing the mass to cement and agglomerate, the condition is still worse. This condition is termed bridging or arching. Some such action and result may have taken place to produce the Warwick phenomena, because, without some such obstructions preventing the ascent of the gaseous currents and arresting their chemical reactions, the furnace could not bridge in the zone of fusion.

The intense heat and great energy of combustion and liquefaction going on in this zone tends to prevent the establishment of such a formation. The sudden interruption of combustion without some cause, such as the previous establishment of obstructions in the upper sections of the furnace, agreeably with our hypothesis, is incomprehensible. Mr. Birkinbine's paper states clearly the good condition of the furnace, so far as the hearth, tuyeres, machinery, hot blast, boilers, etc., are concerned, showing the trouble was not due to any external defects. The appearance of the furnace after shovelling out, showed that the bosh was badly cut away, and, in fact, as much worn as if the blast had extended for years, instead of a few weeks. The cutting of the bosh goes far to establish and support my hypothesis, that the scaffolding was located well above this cut section; in fact, that it was the lodgment and scaffold above that caused the rapid cutting away of the bosh, by forcing the ascending gaseous currents into the channels of least resistance, thus concentrating their force on the sections cut away. This result could not have been produced in a day or two; it is, therefore, at least possible, if not probable, that collections formed during the blowing-in of the furnace.

Engineers and furnace managers will differ as to the treatment adopted by Mr. Cook, viz., stopping operations as soon as the whole

power of the engine was unable to force any blast through the furnace. From a commercial point of view some contend that when a furnace is in such condition the wisest and best plan is to shut down, clean out, and commence anew, but the majority of iron-masters and managers prefer making a determined effort to overcome the difficulties and restore the furnace to good working order.

METHODS OF RESTORING SCAFFOLDED FURNACES.

1. When a furnace is scaffolded the first thing I would do would be to penetrate the furnace casing, if of iron plates, or cut into the brick or stone masonry, and at once establish a dry tuyere or gas-pipe, some 15 or 18 feet above the hearth level, and, as soon as connections were made with the hot-blast main, to inject all the blast possible into the furnace. If this point is below the scaffold, the blast will soon cut or melt its way through it, but if it is above the liquefaction and rapid smelting will soon work its way downward through the formation. In both cases this results in detaching the agglomerated mass from the brick masonry, and, owing to the great weight of the superincumbent mass, the whole scaffold generally gives way.

If the hearth is free, machinery good, and high heats present in hot-blast stoves, the furnace is soon restored to its normal condition, and generally does much better work than immediately preceding the trouble. If the hearth is chilled solid up to or above the tuyeres, it will require a little longer time, but the "gobbing" will soon disappear when the furnace is free above and the proper reactions established again in the zones of chemical action and fusion.

In all furnace plants that we now erect we generally introduce a number of tuyere ports from 15 to 18 feet up in the furnace casing, and encircle the same with an 8-inch gas-pipe having six distinct connections with valves and ball joints, so that when, at any time, the least indications of any collections or lodgments present themselves, we can in a few minutes turn on the blast or steam, as the case may be. Indeed, an occasional application of blast for a short time may sometimes destroy the beginning of such obstructions and keep the furnace steadily working. To have the full area of bosh section is indispensable to good working.

2. Another method adopted is blowing down. This is the old means resorted to, but it cannot be carried out when the furnace is bridged or arched over, because the materials above will remain undisturbed; and if the arched mass is impervious to the gaseous cur-

rents all the power of engines cannot force the blast through the mass. Blowing down, however, is advisable whenever lodgments and funnelling exist, and should generally be continued until the stock level has descended to the lower section of the zone of fusion. The great advantage springing from such blowing down consists in the freeing of the walls and boshes from all collections. They are undermined and cut away by the intense heat developed by the reaction of the gases. Should the operation be stopped, however, when the stock level has descended only to the top or part way down the boshes, a worse scaffold may be formed and left, because much dust and material that will not liquefy descends. Hence, blowing well down is indispensable to success, provided the furnace is supported by firebrick stoves which maintain the heat for days at 1000° F. without any gas.

3. The next method I would notice for dislodging is the introduction of explosive materials into the hearth, which we may term the Witherbee system. I will refer to this hereafter.

4. The last method for removing scaffolds that are impervious to blast is the removal of the tuyeres, opening the front, and shovelling out the materials so as to invite the formation to fall. This is generally successful when a furnace bridges at blowing in, but seldom when a scaffold has established itself, or when, from any cause, the stock has become an agglomerated arched mass.

Over fifteen years ago Mr. Henry McCormick, of the Paxton Furnace and Rolling Mills, Harrisburg, made a successful experiment on No. 1 furnace of their plant. The furnace was badly scaffolded, and his manager and founder had exhausted every means to restore the furnace to good working condition. It became worse and worse until the hearth was filled up with an agglomerated semi-fused mass, which extended several feet above the tuyeres, and no entrance could be effected from below into the furnace. After the manager and assistants gave the furnace up as chilled past all hope, Mr. McCormick had his men drill a small hole into the furnace masonry some 15 or 18 feet above the hearth level, and introduced, I think, a 2-inch gas-pipe. After connection with the hot-blast main, blast was forced into the furnace. In a few hours the scaffold gave way so that the gaseous currents could act. Smelting and liquefaction were re-established, and the chilled masses below were soon bathed and saturated with hot liquid iron and cinder. As soon as an opening was made in the locality of the tuyere arches, the liquid cinder stream flowed out of the furnace, the tuyeres were

soon relieved and brought into action, and within a few days the furnace was all right again.

Mr. Samuel Thomas, of Catasauqua, related to me that when blowing in one of their large furnaces the stock bridged over, and all the power of their immense engines could not penetrate the mass, although he used every possible means for days. But soon after he had introduced a gas-pipe communicating with the boilers and turned on the steam the bridge gave way.

I think on two different occasions the No. 1 Lucy Furnace at Pittsburgh had to contend with difficulties which were superinduced by heavy driving and the bridging of the stock in the upper sections. It would fall in large masses into the zone of fusion and hearth, thus filling them up and preventing liquefaction in these sections. Soon the gas would cease to flow, and the heat in the iron hot-blast stoves would go down, thus impairing the efficiency of the blast in dealing with the trouble. The blast, therefore, instead of becoming converted into carbonic oxide immediately after leaving the tuyeres, would ascend to the zone of chemical action, and, as there would be no consumption of the materials below, therefore no sinkage, the gaseous currents would react above and bridge the furnace; consequently, chilling was inevitable. If the Lucy had been supported with firebrick stoves, and had introduced the tuyere or gas-pipe through ports above, the furnace would have been restored to its normal condition in a short time. I may add that in these instances the stock was shovelled out. The bridge of material could not be dislodged by any of the usual appliances for such cases, and the method adopted for its dislodgment was to discharge a gun or cannon, erected on its end, within the furnace hearth. This was very successful, and showed the nerve of the manager and proprietors.

One other example was the Dunbar Furnace, Fayette County, Pennsylvania. This furnace was remodelled, in fact, rebuilt, under the supervision of Mr. Edmund C. Pechin, engineer and superintendent, during 1876 and 1877. Mr. Pechin made it one of the most modern of our large furnaces—20 feet × 77 feet, supported by three small Whitwell stoves. It was blown-in in the spring of 1877, by Mr. A. B. Desaulles, then superintendent and vice-president. Some weeks after the furnace was in successful operation, owing to inferior coke or other causes, it lodged and bridged some 20 to 25 feet above hearth level on the upper sections of the bosh, and for five days they were unable to penetrate the stock. Meantime

the reactions of the furnace were suspended, the gaseous currents having no effect. There was no combustion and no smelting; and, as a matter of course, no gas flowed from the furnace, so that no fuel or gases entered the Whitwell stoves. Still the latter maintained a heat of from 800 to 1000 degrees during the five days. At last the managers introduced a 4-inch gas-pipe, and it was only a few hours from the introduction of the blast until the scaffold gave way. The furnace was restored in a day or two, and made a blast afterward the aggregate yield of which was over 70,000 tons of metal. The condition of the Warwick Furnace, I think, must have been similar to that of the Dunbar Furnace.

A singular case of wedging and bridging, unlike any of the others, is worthy of being submitted. The largest of the Pennsylvania Steel Company's plant, at Steelton, Pennsylvania, was reduced in dimensions to 17 feet bosh, retaining the same tunnel-head and 10-foot bell as it had previously. After blowing-in again, the working and output of iron were not satisfactory. When the stock level was kept up to the intended lines beneath the hopper the furnace would fall off in yield, the hearth and tuyeres would be bright and open, but the stock would wedge fast on the zone of fusion. After many efforts to find the cause, Mr. Bent, general superintendent of the company, lowered the stock level in the furnace some 30 to 35 feet below the tunnel-head, and dumped in the stock promiscuously. Then the furnace ran up to 100 and 120 tons per day. After much investigation the cause was traced to the large 10-foot bell, which was the cause of throwing the materials against the sides, the fine materials clinging thereto, and the coarse rolling on to the centre. This would naturally invite the whole volume of blast to the channel of least resistance, and allow the fine material to escape the contact of the reducing gases. Thus the accumulation of the fine materials on the boshes caused the stock to wedge in the centre. I need not say that when the bell was adjusted to the size of the furnace the difficulty ceased, and the furnace commenced a fine blast, making one ton of Bessemer pig with one ton of fuel. It is supported by three Whitwell stoves, 18 × 55 feet.

The accumulation of dust and the decrepitation of splint and anthracite coals are frequent causes of scaffolding. As a general thing scaffolding is more frequent in anthracite than in coke districts. In truth, managing anthracite furnaces is much more difficult than coke furnaces. When the hard resonant coke of Connellsville is the fuel,

and the selected ores of Lake Superior the mine used in a modern blast furnace supported by powerful engines, the output of iron is almost without reasonable limit; at the same time there is not required the attention, skill, and experience, or the metallurgical attainments necessary where the conditions are less favorable. The first question when American iron-masters and furnace-engineers meet is, How much are you making? No matter about the cost. In Europe the question is, How low have you got your fuel? There they will spend $100,000 to economize five per cent.

There is no part of the world equal to the West for bringing modern blast furnaces to the maximum of output. The quantity of blast that can be propelled into them is simply enormous. That 25,000 and 30,000 cubic feet per minute could be used in furnaces, if wanted, would not be believed in the iron centres of Europe. I have in my possession a letter from Mr. I. Lowthian Bell, written to the late Mr. Thomas Whitwell, in which he refers to the amount of blast that was blown into Dunbar Furnace in 1878, viz., 20,000 feet per minute. He expresses surprise that it made iron at all with such a volume. Who can imagine what a change must be coming over the dreams of our English cousins when furnaces not larger than Dunbar—for instance, Furnace B of the Edgar Thomson plant—make an output of over 1200 tons per week, and consume now 30,000 feet per minute! It may, therefore be assumed that the West, in its new departure, will soon take the lead in the production of the United States.

Mr. Witherbee's paper describing his methods for the removal of two scaffolds that he had to contend with in the Cedar Point Furnace, is very interesting. It would seem that the first scaffold was dislodged by the introduction of a tuyere some fifteen or twenty feet above the tuyere line. He was caught with another scaffold, due to the fact that his stockhouse scales had been changed from the weight intended. This caused the furnace to be filled for many days with a great excess of ore and limestone to the original charge of fuel. Mr. Witherbee states that when this condition of affairs was discovered he reduced the volume of blast and increased the heat in the Whitwell stoves, but still was not able to master his furnace. It scaffolded badly, as a matter of course. I think that reducing the volume and pressure of blast at that critical moment was a mistake. If the blast had been maintained and quick smelting kept up so long as the liquid iron and cinder would flow from the cinder-notch without regard to the loss of the iron, or of the tapping-hole),

the flow of gas would have been kept constant for the Whitwell stoves, and would have kept up heat enough to prevent the iron from getting too thick to run. But, conversely, by reducing the blast to low pressure and volume, its energies were lost in the lower zones. The stock became more compact, and soon the pressure ceased to force the gaseous currents through the zone of chemical action, resulting in the formation of the scaffold that Mr. Witherbee wished to avoid. A low, light blast must be fatal to a furnace under such conditions, especially if supported with high heats. When the blast is superheated the reaction is almost instantaneous after introduction; but if not supported by volume and pressure, the material in the zones of fusion and chemical action will become stationary, causing scaffolding and bridging, as seems to have been the case with the Cedar Point Furnace. However, no matter what was the producing cause, in the furnace there existed a complete scaffold, and, after all else failed, Mr. Witherbee showed the nerve and self-reliance that few iron-masters or engineers in the United States possess by placing in the seething, red-hot furnace hearth several charges of dynamite or giant powder, incased merely within a piece of pine scantling. He increased each charge in quantity until, if I remember right, some twelve pounds were in the last charge. This brought about the complete dislodgement of the scaffold and filled the hearth with a fearful mass of accumulated rubbish; but the Whitwell stoves, at 1700° F., soon melted everything, when the furnace became free above. This was bold, brave work, and should be called the Witherbee system.

Since it appears to be self-evident that the accumulation of dust, coming from what cause it may, is one of the chief inviting causes of fully two-thirds of all the scaffolds, it would seem that prevention of accumulations would be the chief object and ambition of the furnace manager by determining whether fine material is filled with the stock or results from abrasion, friction, pressure of the superimposed mass in high furnaces, or pressure of blast. At the risk of being considered far too prolix, I would ask the privilege of submitting two cases where the whole of the fuel in the furnace was almost pulverized into dust, and the results of this state of affairs.

In 1869, '70, and '71 the writer was in charge of the erection and management of the Kingsland or Vulcan Iron Works, St. Louis. In the summer of 1871 No. 2 furnace was remodelled, and in July ready for operation. The new rail mill was started and pig iron

was required in large quantities. At the same time several thousand tons were on the banks. Although there was not enough coke on hand for filling up, and although at the same time No. 1 furnace was being robbed of part of its necessary supply; although no coke was on the way from the Pittsburgh region, as the price was considered too high, and although no fresh Big Muddy coal arrived, owing to unknown causes, the furnace was ordered to be blown-in, against my protest. The fuel on hand was 500 to 1000 tons of Brazil, Indiana, block coal. The coal had been on hand for a considerable time, and spontaneous combustion had worked its way partly through it. The furnace continued working for a week after going in blast up to its expected yield, although only an occasional barrow of poor coke was filled, and I could not understand how such good results could come from such fuel. This, however, was soon changed. The boshes had become banked up, after which two days were only necessary to choke the furnace. The iron changed from good gray foundry to white, and finally the blast would not penetrate any distance above the tuyeres. After withdrawing the tuyeres and allowing the dust and fine stock to be withdrawn in large quantities, nothing was found but dead masses of dry dust, mixed with small amounts of ore and limestone. The furnace was choked from tuyere to top, and all efforts were useless, because no coke or fresh coal was on hand. The furnace was therefore cleaned out.

Another great dust scaffold I would mention formed in the Alice of the Etna Iron Works, Ironton, Ohio,—a furnace plant less understood and more abused than any other plant in existence in the United States. The Hanging Rock district of Southern Ohio has been long famous as a charcoal iron centre, Ironton being its chief town. In 1873 a large company was formed to erect furnaces. The chief object to be kept in view was that the furnaces must make iron without the use of Connellsville coke, but the fuel must be bituminous block coal in a raw state, locally termed "stone coal." To attain this end, communications were opened with many engineers, among whom was the writer, who submitted drawings and practical working data, together with the results of the Ferrie self-coking furnaces in Scotland. The chemical composition of the coals of that country and those of the Hanging Rock district were found to be almost identical. The statements of Mr. Ferrie were not taken alone, but were supported by the actual results obtained by Mr. John Hunter, managing director of the Coltness Iron Works, after a two weeks' test. He submitted in writing, in

relation to the saving of fuel, that the old furnaces required 65 cwt. of coal per ton of iron, whereas the self-coking furnaces produced the same results with a consumption of 35 cwt. Two commissions were, therefore, sent by the directors of the Etna Company—one in 1873, the other in 1874—to visit Scotland. Both reported the success of the system, and the Etna Company concluded to adopt it, using, at the same time, Whitwell stoves. A plant of two furnaces, 18 by 87 feet, was accordingly erected, and one was finished under the difficulties resulting from the great panic. In the autumn of 1875 the Alice was completed, and was blown in with only a small supply of coke on hand and little prospect of early arrivals of additional quantities from Pittsburgh, owing to low water in the Ohio. The furnace made an excellent commencement, but soon had to go on one-third coke and two-thirds West Virginia splint coal. As the coal was increased the gas-flow lessened, and the action of the furnace and the output were impaired. The materials sank irregularly in the retorts, and soon would not move at all in some. The generally accepted theory was that the stock was fast in the retorts, and that therefore the whole system was a failure. I alone, owing to closer observations and investigations, thought otherwise, but nothing could withstand the tide of popular indignation. After many other efforts, such as injection of steam in the lower section of the retorts, without any results, I determined to open the ports some 25 feet above the hearth. Instead of finding red-hot stock adjacent to the bosh, I found a bank of coal-dust encircling the bosh fully 6 feet wide, so hard that it required heavy sledging to penetrate it. It was quite dark and cold, and there were not 6 feet of red-hot stock in the central funnel in which the descending materials were wedged. This large dust formation extended upward and downward, and indicated that a large proportion of the fuel, instead of coking and furnishing carbon for the furnace, had pulverized and lodged. After withdrawing the tuyeres and shovelling out over 50 tons there was no change in the condition of the materials. The coal was exclusively converted into dry dust, and it was therefore considered foolishness to persist in keeping the furnace in blast. It was therefore shovelled out for a second trial, which resulted in doing better work, owing to an increase of coke.

Such scaffolds and bridging as this could not have been dislodged. I may state that the coal used in the furnace at the time referred to was a splint, dry block coal from Campbell's Creek, West Virginia. It had a tendency to split into thin slates, like laminated leaves,

which accounts for the pulverization by abrasion and superimposed weight of the high column of stock.

This was the short experiment by which the Ferrie system was judged and condemned. My connection with the work ceased after my contract for building the same was finished. It has been stated, and generally believed, that this plant cost over $1,000,000, whereas the whole cost at the time referred to did not amount to $450,000, and it is admitted, by both foreign and American engineers, that no furnace plant even now in the United States is equal to the Etna either in construction or general design.

I need hardly say that my opinion then was, and still is, that if the management of this plant had fallen into friendly hands, and could have been supplied with coal of different mechanical structure to that of the West Virginia, not having a tendency to decrepitate or split into leaves, the system could have been worked up to as successful results as are attainable with our soft non-coking coal. Far otherwise, however, was the case, and the efforts to promote the use of such fuel in a raw state were abandoned. Even when working three-quarter coke, the retorts were found to increase the yield from 6 to 10 tons per day.

It has been said that the "A" furnace of the Edgar Thomson plant was restored from a chilled-up state by the use of petroleum or coal oil. The injection of hydrocarbons into a blast furnace for promoting and supporting combustion is quite a different matter from their use in rolling-mills, etc., in the form of natural gas issuing from wells and drill-holes. Their successful and economical application to puddling and heating furnaces, boilers, etc., does not prove that they would be equally efficient in the hearth and zone of fusion of blast furnaces, because the requirements and conditions of the one case are quite different from those of the other. Moreover, all applications that I have ever observed, when tested for a short time, have been abandoned. Although the gaseous current leaving the tunnel-head may be in greater volume, it is obtained, nevertheless, at the expense of a lowering of the temperature in the zone of fusion, and to this extent is, therefore, a cooling process.

To support this conclusion I would quote from Mr. I. Lowthian Bell. In his work, *Phenomena of the Blast Furnace*, page 318, he makes observations on solid fuel, containing little moisture, injected at the tuyeres. If, as it states, this does not promote combustion, the hydrocarbons must do so still less. Mr. Bell proceeds to say that many years ago, while visiting the Dombrowa Works, in Poland,

he found the manager of the concern engaged in applying a process largely used, it was stated, at Decazeville, in France. The invention was that of M. Cabral, of that place. It consisted of passing a portion of the blast through a coal fire contained in a large iron chamber, strong enough to support the pressure it had to encounter from the compressed air from the blowing cylinders flowing through it.

I have never been able to understand how the inventor of this mode of applying heat to the smelting of iron expected to accomplish his object. The character of the gases obtained would, of course, depend upon the relative quantity of atmospheric air made to traverse the coal fire. They might consist of carbonic oxide and the hydrocarbons of the coal, or of carbonic acid and steam, or, what is still more likely, there would enter the furnace, at the tuyeres, a mixture of all. Admitting that all of the heat evolved by burning carbon to carbonic acid and hydrogen to water in the external chamber found its way into the blast furnace, there would ensue the refrigeration due to water being reduced to the condition of hydrogen and of carbonic acid to that of carbonic oxide, in which form they would leave the throat. If, on the other hand, hydrogen or its compounds with carbon, or carbonic oxide, were injected, any water formed by the action of the blast would pass again to the state of hydrogen immediately it met with carbon or iron; and, similarly, carbonic acid derived from the oxidation of carbonic oxide would lose half its oxygen from the same cause.

Upon more than one occasion the idea has been suggested of collecting the gases evolved from coking coal and driving them into the furnace. The same objection as regards the use of hydrogen, which has just been mentioned in connection with the use of M. Cabral's proposal, is applicable to this scheme, and any benefit to be obtained from the quantity of carbon contained in the coal-gas would certainly be more than swallowed up by that required to expel the gas from the coal. If, therefore, the gases from a confined coal fire, the hot hydrocarbons or smoke from coking ovens, or powdered coal in a current of atmospheric air, when injected into a furnace, are objectionable and will do more harm than good, how much more injurious must be the injection of cold hydrocarbons in the form of oil!

ON THE SELF-FLUXING PROPERTIES OF CHATEAUGAY MAGNETITE, FROM CLINTON COUNTY, N. Y., AND ITS TREATMENT IN THE BLAST FURNACE.

BY DR. JAMES P. KIMBALL, BETHLEHEM, PA.

THE object of the present memoir is to put on record some practical experiments by the writer in smelting a silicious native magnetite with no other flux than the silicates of its own gangue. This work was undertaken in the spring of 1878 for Messrs. Naylor & Co., of Boston, to whom I am indebted for the privilege of here communicating its results, these having hitherto only been simply announced.* So far as I am aware these are the first instances of the kind in this country that non-calcareous, or rather non-carbonated, magnetites have successfully been used strictly alone as self-fluxing ores in the blast furnace; that is, without the addition of calcareous flux in the form either of limestone, quicklime, calcareous ore, or basic (calcareous) slag.

Previous to the spring of 1878, when the Chateaugay magnetic ore was first brought to my notice, its use had been limited to Catalan forges, after "separation" at the ore bed. The blooms and billets made from it in the several forges of Messrs. Weed & Williams, and of Mr. Williams, were well known in the trade as among the best in the market.

The Chateaugay ore beds proving of great magnitude, and the ore exceptionally low in phosphoric acid, it commended itself for blast-furnace purposes to Messrs. Naylor & Co., who employed me to blow-in the charcoal furnace at Pittsford, Vt., on this ore in the spring of 1878, a previous trial of this ore in the same furnace in the fall of 1877 having proved abortive. This was therefore the first time that Chateaugay ore was successfully smelted in a blast furnace, although since well known as a blast-furnace ore possessing superior and exceptional qualities.

The Pittsford furnace, although rebuilt in 1844, and subsequently improved by the former owner, the late J. Prichard, is one of the few furnaces of the old type with open breast (Sumpfofen) still active in this country. Its improvements on furnaces of the period,

* Bulletin American Iron and Steel Association, XII, 1878, 132, 156.

when this type of charcoal furnace prevailed, consist of a hot blast of moderate heating capacity, and a closed top. It is still supplied only with water-power, limited to a maximum pressure of three pounds. Low stages of water, however, reduce even this low power, thus subjecting the furnace in dry seasons to interruptions in the blast, and occasionally to the necessity of banking. It will be understood that the furnace was operated in the old way of opening the breast several times a day, and "sweeping" out the scoria formed below the tuyeres, by the cooling exposure incident to such a construction. The following were the lines and dimensions of the Pittsford furnace at the time of my experiments. The former have since been modified.

Height of stack,	40 feet.
Bosh, diameter,	10 "
" height,	10 "
Angle of bosh,	62½ "
Crucible,	6½ x 3 feet.
Tunnel head,	6 feet.
Three tuyeres, sides and back,	
Side tuyeres, height,	30 inches.
Back tuyere, "	33 "
Dam,	20 "
Pressure of blast (maximum capacity),	3 pounds.

The result of blowing-in the furnace in the fall of 1877, and previous to my acquaintance with the circumstances, but presumably under the usual practice with a mixture of native hematites and Lake Champlain magnetites, was not successful. After operating a few days with great difficulty, and making a little slag and a little hard iron, she finally chilled. This happened on light charges of *unroasted* ore and 25 per cent. of limestone of the following composition, viz.:

Lime,	33.90
Magnesia,	17.47
Carbonic acid,	45 86
Silica,	2.75
Alumina,	0.55
Ferrous oxide,	0 80
Phosphoric acid,	trace
Sulphur,	none
	100.83

The only analysis of the Chateaugay ore then available was one by Mr. Otto Wuth, of Pittsburgh. His sample, as was afterwards

proved, was considerably leaner than the average of the ore supplied to the furnace. The proportion of slag-making material indicated by the analysis was therefore greater than in the actual working of the ore.

ANALYSIS OF CHATEAUGAY ORE.

Magnetic oxide of iron,	57.29
Ferrous oxide,	3 15
Alumina,	7.92
Silicic acid,	22.18
Lime,	5.96
Magnesia,	3.36
Phosphoric acid,	0.004
Sulphur,	trace
Titanic acid,	none
Water (by loss),	0.30
	100.164
Metallic iron,	44.03
Phosphorus,	0.002

Separating the slag-making ingredients of the ore in the above analysis, they were found to exist in the relative proportion of a fusible acid slag suitable for a charcoal furnace, especially when supplemented by the basic additions from charcoal ashes. In this respect the ore bears a close resemblance to several well-known magnetites of Sweden, the so-called *engœndes* (as those of Dannemora), which are smelted without limestone. I accordingly inferred that the difficulty experienced in blowing-in the Pittsford Furnace on this ore arose from excess of limestone.

The synthetical composition of the slag deduced from the single analysis above given, without reference to the ashes, would be as follows, viz.:

Silica,	56.55
Alumina,	20.19
Lime,	15.19
Magnesia,	8.56
	100.49

In order to test experimentally the slag-making properties of the ore, which had never been applied to a blast furnace except in the instance named, I made a series of fusions of the ore in brasqued crucibles, with different proportions of native limestone, and also by itself, and obtained a perfect separation of metal and a highly fusible slag from the ore by itself, and only slightly less fusible slags when mixed with lime-

stone up to ten per cent.,—the degree of fusibility being in inverse ratio to the proportion of limestone additions, as far as could be judged by the eye. The limestone used, it will be noticed, is highly magnesian. The buttons of metal, however, averaged 52.25 per cent., showing as above remarked, a difference of eight per cent. in favor of the richness of the ore, as delivered, compared with the sample analyzed by Wuth. The relative proportion of the ingredients, exclusive of the iron, was assumed to be sufficiently indicated by the analysis. In point of fact, the ratio of silica to alumina proved to be 1 part of alumina to 4.27 of silica, instead of 2.8 of silica, as in the sample analyzed by Wuth.

The slag-making components of Chateaugay ore are essentially free quartz, feldspar, actinolite and chlorite. No *carbonate of lime* is present, the lime being wholly referable to a compound silicate with magnesia in actinolite. Its essential difference from the great majority of American magnetic iron ores in the market, is in its possession of a notable proportion of alumina,—referable to its presence in feldspar, rather than in the chlorite,—by far a more common silicate in native magnetites.

Previous to my taking temporary charge of the Pittsford furnace, the whole stock of Chateaugay ore had been roasted in heaps at my request. Wishing to proceed cautiously in the experiment, and with the object in view of securing a good flow of cinder, I began with a small charge of old acid slag from the dump, and followed with small charges of limestone gradually reduced and finally replaced with slag from the hearth of the furnace as follows:

Date.	Charges.	Coal, bushels.	Ore, pounds.	Limestone, pounds.	Slag.	
May 2, 1878.	8	30				
" 2, "	1			75		
" 2, "	2	30	400	36		
" 3, "	10	30	400	36		¼ pound pressure, cold blast.
" 3, "	10	30	400	36	60	
" 4, "	25	30	500	45		
" 5, "	21	30	500	45	75	First cast 2310, foundry; warm blast.
" 6, "	8	30	500	45	75	
" 6, "	3	30	500	25	75	
" 6, "	4	30	600		75	
" 6, "	1	30	600		114	
" 12, "	32	30	1075		100	
" 18, "	31	30	1175		75	
June 1, "	34	30	1125		85	
" 15, "	35	30	1000		45	
" 27, "	35	30	1025		60	
" 28, "	34	30	925		60	
July 5, "						Furnace banked for want of water-power.

On the 16th of May, when I turned over the charge of the furnace to Mr. Gilman Prichard, with William McCoy as founder, it was on

a full burden, and with a little over 6 per cent. of slag from the hearth, applied by way of supplementing, or rather extending the normal proportion of slag-making material of the ore charged. I may here remark, that the fluctuations in the number of units of iron in the ore, as shown in my extract from the blast-book (Table II), are only apparent, it not always being practicable to deduce the average yield of an ore for so short a period as one week; the first cast or two in a week generally being to the credit of the previous week. The difference is considerable when the furnace is working up.

Towards the last of this short blast the failure of the water-power made it necessary to run the furnace slowly, and with a light burden, until at length suspended on July 1st, and banked.

In order to use up the stock taken from the furnace after chilling, consisting of about half Chateaugay ore, one quarter limestone, and one quarter charcoal, all in a damp state, some two per cent. of it was charged after the second week. No account of this charge is made in the table, as its practical effect was simply to increase the apparent yield of the ore about 0.5 per cent., while adding some some 0.25 per cent. limestone to the charge.

With the renewal of the water-power in the winter, the furnace was opened on December 11th, after being banked some five months, and again blown-in by myself on the next day with the same practice and with similar results as in the previous blast. This blast was of short duration from want of coal, and the furnace was again banked January 8th, 1879.

April 28th, 1879, the furnace was again started on Chateaugay ore as before. No limestone was used till the sixth week, when it became desirable to keep the slag as basic as practicable within the limits of easy fusibility. Two per cent. of limestone was therefore added to the charge, and the charge of slag reduced to about the same extent. The average proportion of slag charged to the amount of ore used throughout the whole blast, ending July 10th, 1879, was 6.2. As will be seen by reference to the table, the new supply of ore proved richer than the previous one, and the relative consumption of fuel was accordingly reduced.

In the eighth week of the blast an interruption occurred of eight days, during which the furnace was banked for want of charcoal. Such an interruption, like the former ones, was of course attended with a large consumption of fuel, which, averaged upon short blasts, runs up inordinately the fuel account.

It may be proper to say in explanation of such a succession of

interruptions, that the Pittsford furnace plant had not then actually passed into the hands of the present owners, and that at the time of the above experiments, it was not regularly "in commission."

The normal consumption of charcoal was less than 100 bushels to the ton of iron, the average for the five weeks of regular blast (3d to 7th inclusive) being some 97 bushels. The composition of this charcoal was hard and soft in about equal proportion.

After the interruption last mentioned the furnace continued in blast till July 10th, when it was blown-out for repairs to the hearth, which was found to have cut considerably between the bosh and tuyeres, probably thus affected by the repeated banking. The record given is for all the full and uninterrupted weeks of the blast.

The pressure of blast was generally governed by the stage of the water and the available power. As the charcoal was far from the best quality, through admixture of spruce, $\frac{3}{4}$ to $\frac{7}{8}$ pounds was about the maximum pressure employed, according to the power. The continual sweeping of the hearth, the cooling effect of this practice, and its tendency to bodily settling of the stock or to slips, rendered it necessary to keep the furnace as hot as practicable—the open construction of the hearth not admitting of the production of forge iron, at least, with a magnetic ore.

PLATTSBURGH FURNACE.

I now proceed to describe some further experiments with Chateaugay ore in the above-named furnace. Although this furnace is of modern pattern, with steam-power, closed front and closed top, its actual cubical capacity is somewhat less than that of the Pittsford furnace, with the same height being one foot less in the bosh. Unfortunately, for the purpose of comparison between the experiments conducted in these two furnaces, the conditions belonging to the fuel were grossly unequal. A similar inequality attaches to any comparison of the Plattsburgh furnace at the period referred to with other charcoal furnaces in general, arising from the circumstance that it was supplied only with soft coal, and that of the very poorest description.

The Plattsburgh or Norton furnace was built in 1877–78 by the late C. F. Norton, as an auxiliary to his extensive saw-mills, with the object of utilizing their refuse, by converting it into charcoal, and consuming this on the premises as a blast-furnace fuel. The only directly available fuel for this furnace, comparatively remote from hardwood timber, was therefore made from the butts, sides and edges

of pine and hemlock logs, hemlock being in much the larger proportion. Ill adapted as such soft woods are to charcoal for a blast furnace, the stock on hand proved poor of its kind, from the circumstance that it had been accumulating for several years, and had therefore suffered from exposure to the weather. A large portion of it, in the interior of the piles, proved quite rotten from fermentation. This condition of the wood led to unevenness in the quality of the charcoal, the outer sound or fresher portions of the piles affording a soft and weak fuel, while the weathered portion yielded a coal quite unfit for its purpose. Farther inequality in the charcoal arose from the difference between butts, slabs and edges, as each sort was piled by itself, and coaled apart. This explains the large consumption of fuel recorded in the following experiments. It would have been even greater, but for an occasional admixture of forest coal made from the ordinary run of soft and hard coaling woods in our northern forests, viz., in the proportion of about one-quarter soft.

The Plattsburgh charcoal averages about 12 pounds to the bushel when fresh from kiln, or about 13 pounds from shed. The charcoal from weathered wood and edges was exceedingly soft and pulverulent. The forest coal was of good weight, or some 16 pounds to the bushel.*

Handicapped as any record of the work of the Plattsburgh furnace must be under such adverse conditions affecting its consumption of fuel, the work here recorded affords nevertheless a remarkable example of blast-furnace practice when considered with reference to these conditions. It is obvious that an excessive consumption of fuel in any case, by proportionately reducing the capacity of a furnace for ore, practically diminishes its whole working capacity. In other words, the excess of fuel takes up room properly belonging to ore. The production of iron is accordingly out of proportion to the cubical capacity of the stack.

The following are the dimensions, etc., of the Plattsburgh furnace:

Height of stack,	40 feet.
Bosh,	9 "
Diameter of hearth,	3½ "
Tuyeres,	8
Tunnel head,	6 feet.
Capacity of hot blast,	600° to 700°

At the instance of the lessees, Messrs. Naylor & Co., I took temporary charge of the Plattsburgh furnace on March 11th, 1879,

* See a paper, volume viii, Transactions, by Professor Egleston on Charcoal in Kilns, with reference to the coaling operations at the Norton Furnace.

and blew it in on calcined Chateaugay ore without limestone, using to start with, some basic slag from the Crown Point anthracite furnaces—no other blast-furnace slag at hand being sufficiently free from suspicion of phosphoric acid. This was followed by slag from the furnace hearth in charges gradually reduced from 8 per cent. of the ore charge in the first week, to some 3 per cent. in the second week. At the end of the third week about 3 per cent. of limestone was charged, together with about the same proportion of the slag of the furnace, used as it was made. This continued to be the practice for several weeks. In the tenth week the charge of limestone was doubled, and the slag charge reduced to about 2 per cent. After this the charge of limestone was gradually increased to about 13 per cent. With about 6 per cent. of limestone in the twenty-first week, the use of slag was entirely dispensed with. This change was made in order to keep the metal low in silicon by means of as basic a slag as practicable, the ore failing to maintain its richness as at first delivered.

A pressure of blast of $\frac{3}{4}$ to $1\frac{1}{4}$ pound was maintained throughout the blast, the lower pressure when using soft charcoal alone, and the higher when this was mixed with forest charcoal in the proportion of $\frac{1}{4}$ to $\frac{1}{2}$ of the latter.

The furnace worked uniformly hot throughout the blast, producing but little white and mottled iron, although efforts were made to keep the furnace on this quality. The rapid and intense combustion of so soft a fuel accounts for the failure to produce other than gray iron, except as an accompaniment of a scouring cinder caused by occasional slight slips or other irregularities.

After the first week the furnace was under the personal charge of the founder, Mr. J. B. Harnden. Since the exhaustion of the old stock of saw-mill charcoal, the Plattsburgh furnace, with Mr. Harnden as founder, has had a long and successful blast on Chateaugay ore and forest charcoal, the improvement of the fuel having been attended with a diminished consumption (about 150 bushels). From 12 to 14 per cent. of limestone is still used. The ore as at present supplied varies in metallic iron from 46 to 50 per cent.

SELF-FLUXING PROPERTIES OF CHATEAUGAY ORE.

The slag-making material of an ore graded according to richness, will of course vary in quantity with the grade. Thus it will be seen in the table of analyses of Chateaugay ore, that when the ore reaches the higher grades, the slag-making material becomes of less im-

portance as it falls off in relative quantity. If this ore were mined for market up to the same high grade as shown by some of the special averages, the fusibility of its silicious ingredients would call for no particular consideration. So, too, the higher grades of Chateaugay as mined, while characterized by slag-making properties, in kind the same as above described, possess these properties only in a minor degree. The difference between a 44 per cent. ore as in Wuth's sample (I) and a 60 per cent. ore as in Chandler's (V), is equal to a difference of over 25 per cent. in slag-making ingredients. As the ore delivered to both furnaces at the time referred to, averaged for considerable periods 52, 55, 58, and 59 per cent. of metallic iron, it required, when smelted alone for a suitable flow of cinder, the addition of small proportions of its own slag, replaced in the case of a more basic operation, by limestone.

The slag from both furnaces when running without limestone was characterized by uniform physical properties, viz., an amethystine glassy surface and a gray porcellaneous centre, the difference being due to the conditions of its cooling.

ANALYSIS OF SLAG, PITTSFORD FURNACE.

Silica,	56.650
Alumina,	5.303
Magnesia,	6 036
Lime,	29.750
Ferrous oxide,	1.296
Potash, etc.,	3.217

This analysis, which may be regarded as that of a normal slag from Chateaugay ore smelted with charcoal without extraneous flux, approximately affords the empirical formula $5RO$, R_2O_3, $13SiO_2$. Thus it will be seen to be an acid slag between a bisilicate and a trisilicate. Its composition closely approaches that of fusible blast-furnace slags *par excellence*, like Bodeman's for instance (silica, 56; lime, 30; alumina, 14). As compared with this slag the deficiency in alumina is made up in protoxide bases like magnesia and the alkalies. It approaches the composition of an aluminous augite, with excess of silica and alumina, due to the feldspathic gangue of the ore, accompanying calcareo-magnesian silicates of the amphibole type, and to the admixture of these minerals with free quartz.

TABLE I.

ANALYSES OF CHATEAUGAY MAGNETIC IRON ORE (COMMERCIAL SAMPLES).

	I.	II.	III.	IV.	V.	VI.	VII.
Magnetic oxide of iron	57.29	86.14	80.76	83.49	82.57	.....	.....
Ferrous oxide	3.15	.....	.....	.....	.....	.....	.....
Manganous oxide	.....	0.07	trace	trace	0.39	.....	0.23
Alumina	7.92	1.01	3.11	.....	1.67	2.505	3.244
Lime	5.96	2.79	1.59	.....	3.54	1.877	3.151
Magnesia	3.36	trace	1.02	0.515	1.67	0.266	1.366
Silica	22.18	10.16	13.25	.....	10.18	13.60	13.87
Insoluble	.....	.....	.....	15.240	.....	.....	.....
Sulphur	trace	0.09	0.28	0.89	0.06	0.041	0.272
Phosphoric acid	0.004	0.06	trace	0.047	0.128	0.053	0.580
Titanic acid	.....	.....	0.07	0.46	trace	.....	.....
Water	0.34	.....	.....	0.16	.....	0.130	0.210
Loss by ignition	.....	.....	.....	.....	.....	0.170	.....
Alkalies	.....	.....	.....	.....	.....	1.037	1.037
Total	100.204	100.32	100.08	100.802	100.208	.....	.....
Metallic iron	44.03	60.28	58.20	60.459	59.780	56.283	56.505
Phosphorus	0.002	0.026	.....	0.020	0.056	0.023	0.025

I. By Dr. Otto Wuth.
II. By G. W. Maynard.
III. By A. H. Howe.
IV. By Dr. F. A. Genth.
V. By Dr. C. F. Chandler.
VI. By Mr. Billings, Norway Iron Works, South Boston.
VII. Mean average.

TABLE II.

EXTRACT FROM BLAST BOOKS, PITTSFORD AND NORTON FURNACES.

	Soft wood, cords.	Charcoal, bush.	Limestone, per ct.	Slag, per cent.	Pig iron, tons 2240 pounds.	Yield, per cent.	REMARKS.
PITTSFORD FURNACE.							FIRST BLAST.
2d week ending May 15, 1878.		121.65	None.	9.01	53.20	49.64	
3d "		107.66	"	6.45	63.81	56.45	
4th "		131.32	"	5.87	59.70	48.07	
5th "		107.24	"	3.62	67.20	57.96	
6th "		118.33	"	3.74	66.44	57.03	
7th "		113.05	"	5.54	62.89	55.15	
8th " ending June 26, 1878.		123.34	"	7.74	58.13	57.61	Furnace banked July 1.
Mean average.....		116.71	"		61.62	54.56	
							THIRD BLAST.*
2d week ending May 11, 1879.		152.	None.		39.	42.	
3d "		103.	"		54.	60.	
4th "		86.	"		63.	62½	
5th "		108.	"		74.	66.	
6th "		96.	"		56.	60¼	
7th " ending June 15, 1879.		91.13	2.7	2.7	68.8	66.26	Rest of blast interrupted.
Mean average.....		106.			59.13	59.54	
NORTON FURNACE.							PLATTSBURGH.
14 weeks ending June 15, 1879.		175.46	3.78	4.01	54.98	58.38	Exclusive of first week of blast.
16th week.....		185.20	5.87	2.40	58.53	57.90	
17th "		218.55	6.12		55.68	51.66	
18th "		250.00	5.49	1.01	47.16	46.84	
19th "		198.73	6.07	2.60	56.96	53.72	
20th "		209 99	5.90	2.36	59 05	52.37	
21st "		203 83	5.74		61.03	53.60	
22d "	6 50	194 84	6.42		56 66	55.63	
23d "	29.25	201.76	6 08		46.39	48.15	
24th and 25th weeks..... ..	20.00	168.21	6.62		39 83	60.79	
Month ending Sept. 27.....	19.36	188.09	7.54		58.61	57.35	Furnace stopped one week for repairs.
" " Oct. 31.....		220.93	9.47		58.13	51.97	
" " Nov. 28		243.21	10.61		50.79	40.87	
" " Dec. 26.....		179.76	11.54		62.47	57.21	
" " Jan. 23, 1880.		205.87	13.44		54.68	49.49	
" " Feb. 22		185 62	14.68		53.23	46 83	
" " Feb. 29.....		186.73	13.24		53.66	46.49	
Mean average.....		200 98			48.69	52 30	

* A second blast, of very short duration, commenced December 12, 1878.

TABLE III.

ANALYSES OF PIG IRON AND ACCOMPANYING SLAGS, PITTSFORD FURNACE.

	PIG IRON.						CORRESPONDING CINDER.							
	No. Pig.	C Comb.	C	P	Si	S	FeO	CaO	Al_2O_3	MgO	SiO_2	P	P_2O_5	K_2O
May 1878.....	1	3.750		.063	1 860	.002								
June, 1878....	"			.046	2.563									
Dec. 31, 1878.	"			.051			1.296	29.750	5.303	6.036	56.650		.048	3.217
Jan., 1879.....	"			.054	2 17									
Jan., 1879.....	"			.056	1.53									
March, 1879.	"			.032		.002								
March, 1879.	"			.063										
Miller, Metcalf & Parkin.....	"													
	"			.034	1.98									
June 12, 1879.	"	2.910		.061	0.600									
	"													
NORTON FURNACE, PLATTSBURGH.														
April 1, 1879.	"	3.668	0.03	0.055	3.042									
Apl. 25, 1879.	"	3.572	0.03	0.043	3.233									
June 7, 1879.	"			0.026	1.590						55.58	0.003		
June 14, 1879	"			0 030	1.790						52.61	race.		
June 19, 1879.	"			0.029	0.638						53.74	0.014		
Calculated from Wuth's Analysis I, Table I.....								15.19	21.193	8.56	56.55			
Calculated from Chandler's Analysis V, Table I.....								20.58	9.709	9.709	59.183			

ON THE WEIGHT, FALL, AND SPEED OF STAMPS.

BY H. S. MUNROE, E.M., PH.D., ADJUNCT PROFESSOR SCHOOL OF MINES, NEW YORK CITY.

AN elaborate discussion under this heading formed a chapter in one of the reports made by Professor Raymond as Commissioner of Mining Statistics.* In a subsequent report† was printed a paper, by Mr. William Main, Jr., of Columbia, South Carolina, containing a theoretical investigation into the effect of the velocity of impact on the effective duty of stamps.

A visit to the Lake Superior copper region last summer suggested an inquiry into the relative efficiency and economy of the enormous steam stamps of the copper-mills, as compared with the results obtained with the cam and tappet stamps commonly used in the West. The atmospheric stamp used at the Phœnix Mill promised to add interest to the inquiry, as giving an example of unusually high speed, this stamp making 150 drops per minute.

In introducing his subject Dr. Raymond makes the following remarks, which are quite *apropos* of the present investigation:

"In considering the economical application of stamping machinery, we meet, at the beginning, with serious difficulties in obtaining accurate data for comparison. The weight and fall of stamps vary as the shoes and dies wear out; and this may lead to a change of speed also. Moreover, defects in engines, boilers, or machinery for the transmission of power, may occasion serious losses, which cannot fairly be charged to the arrangements of the stamps proper. Again, the capacity of stamp-mills is directly dependent, in some degree, upon the nature and extent of discharge, fineness of screens, and other peculiarities of the battery. Finally the hardness and tenacity of the rock crushed varies so much that comparisons between different localities cannot be implicitly trusted. The safest experiments are those made in the same mill, by changing first one and then another condition of working; but this is seldom possible for such

* Mineral Resources West of the Rocky Mountains, 1871, p. 380.

† Mineral Resources West of the Rocky Mountains, 1873, p. 345.

conditions as weight and lift of stamps, and only within narrow limits for their speed.

"We may eliminate questions of friction, transmission, and generation of power, in the case of stamps, by measuring the power actually developed by their fall. Thus the weight, multiplied into the fall in feet, and the number of drops per minute, gives us exactly the number of foot-pounds exerted by each stamp. Dividing by 33,000, the number of foot-pounds per minute in one-horse power, we have the horse-power per stamp, from which the effective power of the whole mill may be obtained. Dividing the amount of rock crushed daily by the effective horse-power gives us the daily amount per horse-power; and this is the best measure that can be obtained for the effectiveness of the stamps. A complete discussion of the subject would require us to determine the exact influence of the discharge, etc., and the exact resistance offered by different classes of rocks, for both of which points the data are wanting."

Dr. Raymond then gives a number of tables comparing a large number of stamp-mills in Colorado and California, giving the weight, fall, and speed of the stamps, and the tons crushed per horse-power developed, and concludes the paper with arguments in favor of high speed for stamp batteries.

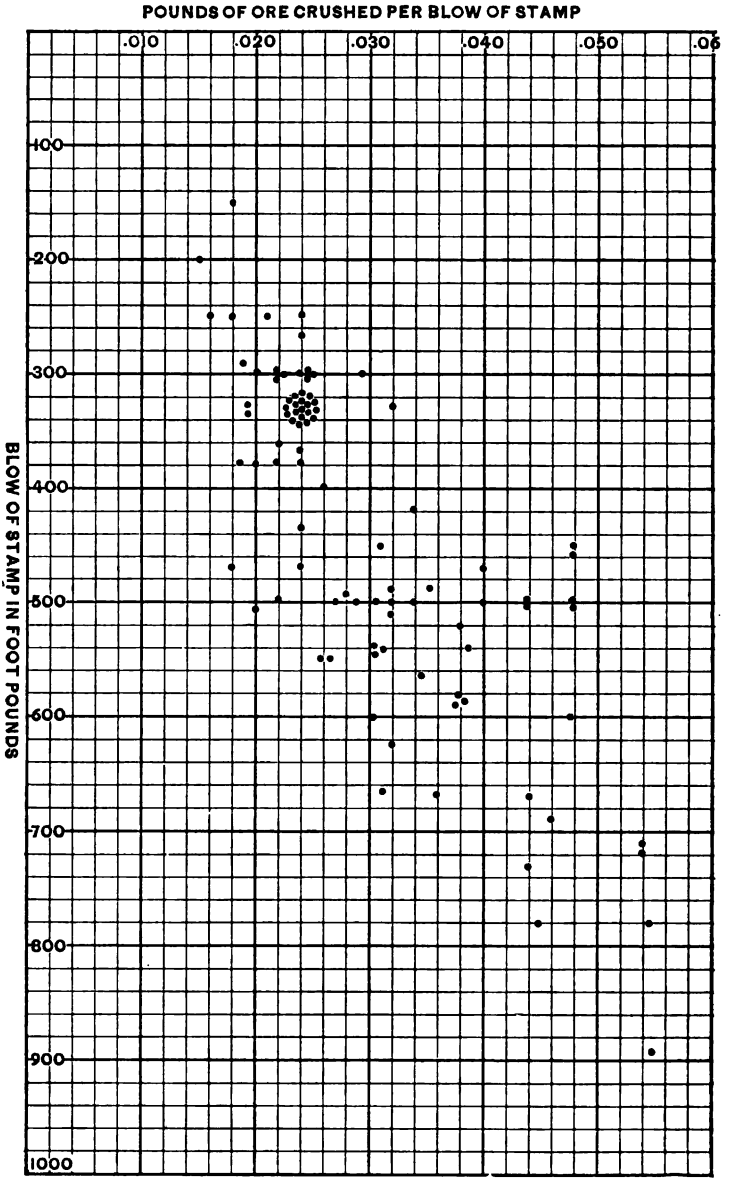
In Mr. Main's paper the author draws an argument in favor of a high drop, or great velocity of impact, from the velocity with which vibrations are transmitted through rock. The greater the velocity of the stamp, the quicker it will come to rest, and the less time and opportunity there will be for the vibrations to be transmitted through the rock into the mortar and the foundations of the battery. In the case of a 400-pound stamp with a 15-inch fall the vibrations would extend through seven inches of granite before the stamp comes to rest. A 100-pound stamp with four times the fall (or the equivalent of this fall in the form of acceleration by springs or steam-power), the same number of foot-pounds being exerted, the vibrations would extend but $3\frac{1}{2}$ inches into the rock. Or if we suppose the rock to be crushed to be $3\frac{1}{2}$ inches thick, in the first case one-half the force has passed through the block and into the anvil, and in the second case the whole power of the blow is confined to the rock.

While Mr. Main's argument is well founded as regards the crushing of solid blocks of ore, it does not altogether apply to the crushing of broken material. Vibrations will not be transmitted through a mass of broken rock with the same speed that they will pass through solid granite; and in practice it may even prove of advan-

DIAGRAM I.

SHOWING THE CRUSHING EFFECT, PER SINGLE BLOW, OF STAMPS OF DIFFERENT WEIGHT AND FALL.

(Data from Raymond's "Mineral Resources," 1870.)



tage that a portion of the force should be transmitted through the upper layer of fragments, in order that those below may be crushed.

EFFECT OF WEIGHT AND FALL OF STAMPS.—In order to determine the effect of weight, fall, and speed on the crushing capacity of a stamp we must eliminate as far as possible other conditions having influence on the result. By taking for comparison stamp-mills crushing gold ores, we may secure a certain uniformity in these conditions, viz.: similarity of material crushed, gold ores being usually quartzose; and, within a narrow range, equal fineness of crushing, very fine screens being uniformly employed. Silver-mills, and gold-mills crushing cement, have been excluded from this preliminary discussion; the first for the reason that silver ores of different localities are much less uniform in character than gold ores, and the latter because the coarse screens used increase largely the capacity of the stamps.

To simplify the discussion weight and lift may be combined and expressed as foot-pounds. In order to eliminate the effect of speed, that is, the varying number of blows per minute, we may calculate and compare the pounds of ore crushed per single blow of the stamp.

The result of such a comparison is shown in Diagram I, embodying data from the report of the Commissioner of Mining Statistics for 1870, from nearly 100 California stamp-mills treating gold ores.

It will at once be seen from the above diagram that although there is considerable variation in the amount crushed by stamps of equal foot-pounds, yet there is evidently a decided increase of effect with the heavier blows.

In order to eliminate, as far as possible, conditions having effect on the product other than the foot-pounds developed by the fall of the stamp, such as differences in character of ore, etc., we may take groups of ten to thirty mills having stamps of nearly equal weight and fall, and compare the average efficiency of these mills with the efficiency of others using heavier and lighter stamps. The result of such a comparison is shown in the following tables:

TABLE I.

CALIFORNIA GOLD-MILLS, 1869.

(Data from Raymond's "Mineral Resources," 1870.)

MILLS.	1 Average weight of stamps.	2 Average drop. (Inches.)	3 Average speed (drops per min.).	4 Average foot-pounds per drop.	5 Pounds ore crushed per drop.	6 Pounds ore crushed per 1000 ft.-lbs.
10 mills, 800–950 lb. stamps.	850	10.3	60	729.4	0.0464	0.0636
30 mills, 600–750 lb. stamps.	666	9.1	68	507.4	0.0344	0.0677
10 mills, 500–600 lb. stamps.	555	8.6	65	400.9	0.0265	0.0660
18 mills, 500 lb. stamps.	500	8.0	60	333.3	0.0235	0.0705
15 mills, 300–600 lb. stamps.	487	6.2	65	267.0	0.0204	0.0764

TABLE II.

CALIFORNIA GOLD-MILLS, 1875.

(Data from "Mineral Resources," 1876.)

MILLS.	1 Average weight of stamps.	2 Average drop. (Inches.)	3 Average speed (drops per min.).	4 Average foot-pounds per drop.	5 Pounds ore crushed per drop.	6 Pounds ore crushed per 1000 ft.-lbs.
10 mills, 750–900 lb. stamps.	830	9.9	75	685.6	0.0395	0.0576
30 mills, 600–900 lb. stamps.	711	8.9	76	525.	0.0339	0.0656
10 mills, 600–750 lb. stamps.	667	7.8	76	435.	0.0303	0.0696

TABLE III.

COLORADO GOLD-MILLS, 1869.

(Data from Hague's "Mining Industry," p. 574.)

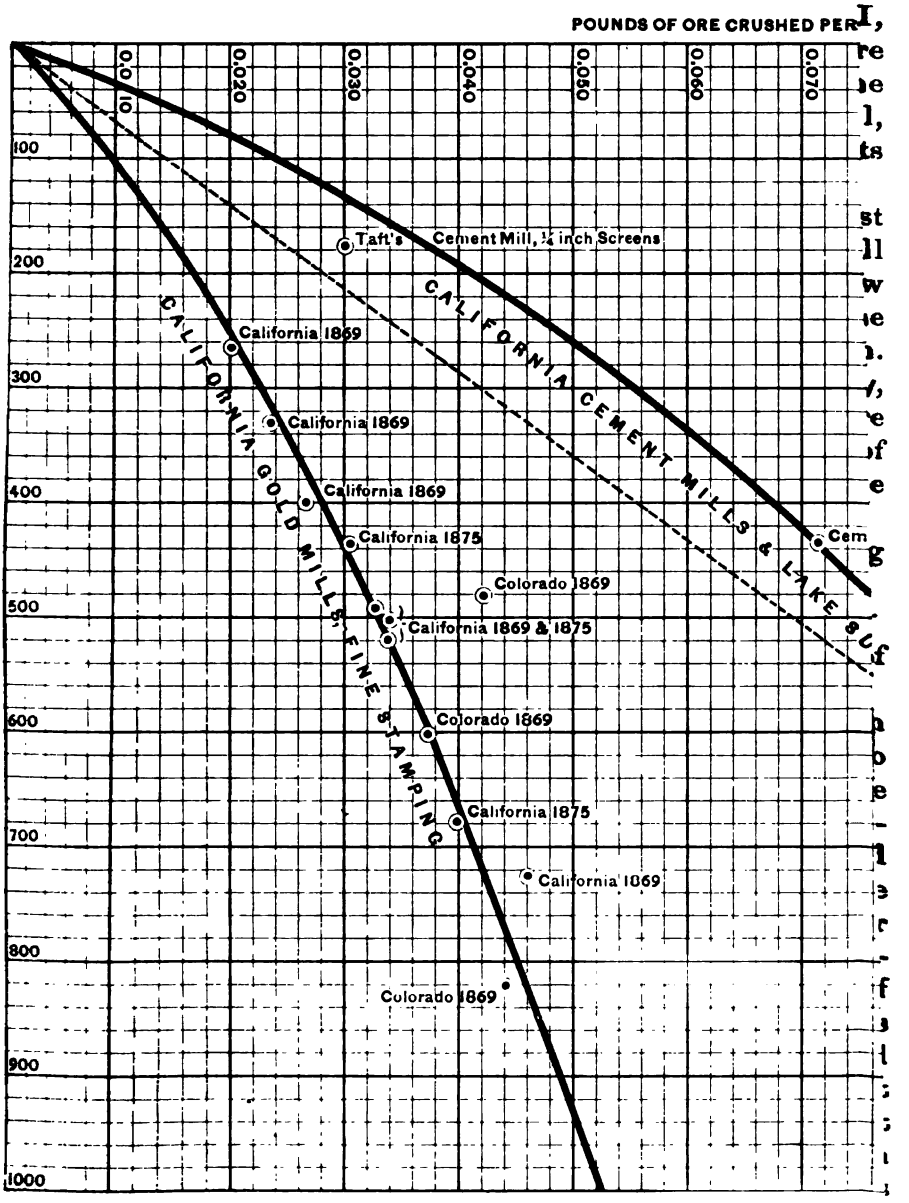
MILLS.	1 Average weight of stamps.	2 Average drop. (Inches.)	3 Average speed (drops per min.).	4 Average foot-pounds per drop.	5 Pounds ore crushed per drop.	6 Pounds ore crushed per 1000 ft.-lbs.
10 mills, 500–900 lb. stamps.	696	14.2	27.5	822.5	0.042	0.0511
13 mills, 450–750 lb. stamps.	533	13.5	32.0	600.1	0.037	0.0617
10 mills, 350–500 lb. stamps.	475	12.2	32.5	483.5	0.042	0.0870

The mills in the different tables are arranged according to the foot-pounds developed in the fall of the stamp. An inspection of the columns of weight and drop will show that it is the practice,

DIAGRAM 39

SHOWING THE AVERAGE CRUSHING EFFECT, PER SINGLE BLO

See Tables I, II, III

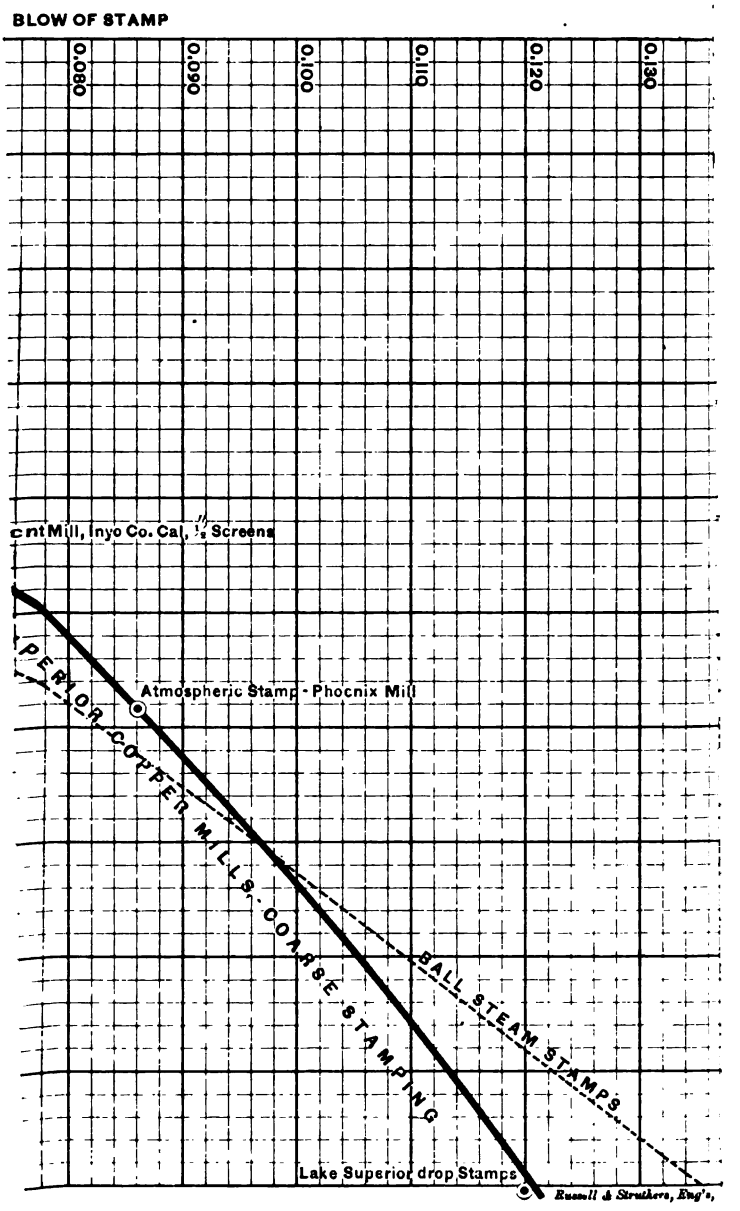


II.

81

W, OF STAMPS WITH FINE AND COARSE SCREENS.

, and IV.



both in California and Colorado, to give higher drops to the heavier stamps. Column 5 shows that the amount of rock crushed increases with the force of the blow, while column 6 shows that heavy blows are not quite as economical as light ones.

These facts are brought out even more clearly in Diagram II, in which, among other things, the results given in the tables are plotted carefully to scale. The effect of averaging in each case the results of a number of mills having stamps of equal weight and fall, shows itself in a striking manner in the diagram, the plotted points falling almost in a single line.

We may go farther than this, and by use of the method of least squares average th se averages and determine the curve which will approximate the results most closely, and thus determine the law which governs the relation between the weight of the blow and the ore crushed, at least within the limits of the data under discussion. By forming a series of equations for different values of x and y, making x equal to the foot-pounds and y equal to the pounds of ore crushed in each case, and combining the equations by the method of least squares, we obtain a series of normal equations from which the constants for x and y may be determined.

The California stamp-mills thus treated give the following formula:

$$y^2 + 0.04\, y = 0.0000048\, x,$$

which is the equation of a parabola passing through the origin of co-ordinates and with its vertex below the axis of x.

This curve has been traced on Diagram II, and it will be seen that it coincides very closely with the plotted points, and serves to express clearly the relation between the force of the blow and the amount of ore crushed. The amount of ore crushed increases regularly with the force exerted; but the amount crushed per foot-pound is somewhat less with stamps giving a heavy blow than with those giving a light blow. The Colorado stamps, as they work under somewhat abnormal conditions, have not been used in the determination of the curve, but it will be seen that with the exception of the mills with light stamps, their agreement with the general law is quite close. These light stamps give very high results; but careful inquiry, made on a recent trip through Colorado, casts some doubt on the accuracy of the data involved. The fact that there are at present no mills in Gilpin County with stamps developing less than 500 foot-pounds, and only two mills approximating this figure is also of interest in this connection.

We may, in a similar manner, compare the Lake Superior stamp-mills with each other and with the cement-mills of California, which have equally coarse screens.

TABLE IV.

STAMP-MILLS WITH $\frac{3}{16}''$ SCREENS.

MILLS.	1 Average weight of stamps.	2 Average drop. (Inches.)	3 Average speed (drops per min.).	4 Average foot-pounds per drop.	5 Pounds ore crushed per drop.	6 Pounds ore crushed per 1000 ft. lbs.
29 Ball stamps, Lake Superior.	4200	20?	90	26,500	1.840	0.070
3 mills, drop stamps, Lake Superior	1100	11	51	1,007	0.120	0.120
Atmospheric stamps, Phœnix Mill, Lake Superior	270	16	150	585	0.086	0.146
Cement-mill, Inyo Co., Cal., 1869, half-inch screens	650	8	60	433	0.071	0.164
Taft's Mill, Eldorado Co., Cal., 1869, quarter-inch screens	300	7	80	175	0.030	0.171

The foot-pounds per drop for the atmospheric stamp has been calculated on the supposition that the velocity of the descending stamp, at the moment of impact, is equal to the velocity of the crank-arm. As the blow is practically delivered when the downward movement of the crank-arm is most rapid, or immediately afterward, this assumption cannot be far from the truth. The foot-pounds per drop for the steam stamps was calculated in each case by taking into account the acceleration due to the steam pressure, making allowance for cut-off as well as acceleration due to gravity. The effect of the cut-off on the final velocity of the stamp is small, especially when compared with the resulting economy of steam. As the data for the calculation of the force of the blow of the steam stamps were in some cases imperfect, no attempt is made to compare the efficiency of the different Ball stamps, or to determine the effect of weight, speed, steam pressure, cut-off, etc. Such a comparison might develop many interesting facts.

Omitting the Ball stamps, the formula obtained by the method of least squares for these stamps with $\frac{3}{16}$ inch screens is

$$y^2 + 0.07\,y = 0.000023\,x.$$

This curve also has been traced on Diagram II, and coincides closely with the plotted points. The Ball stamps, developing an average blow of about 26,500 foot-pounds, and, therefore, far beyond the limits of the diagram, give much better results than would be

indicated by the above equation. Including the Ball stamps, the equation becomes

$$y^2 + 1.67\ y = .0002437\ x.$$

The curve corresponding to this formula is shown in a broken line, passing above the drop stamps and somewhat below the other mills.

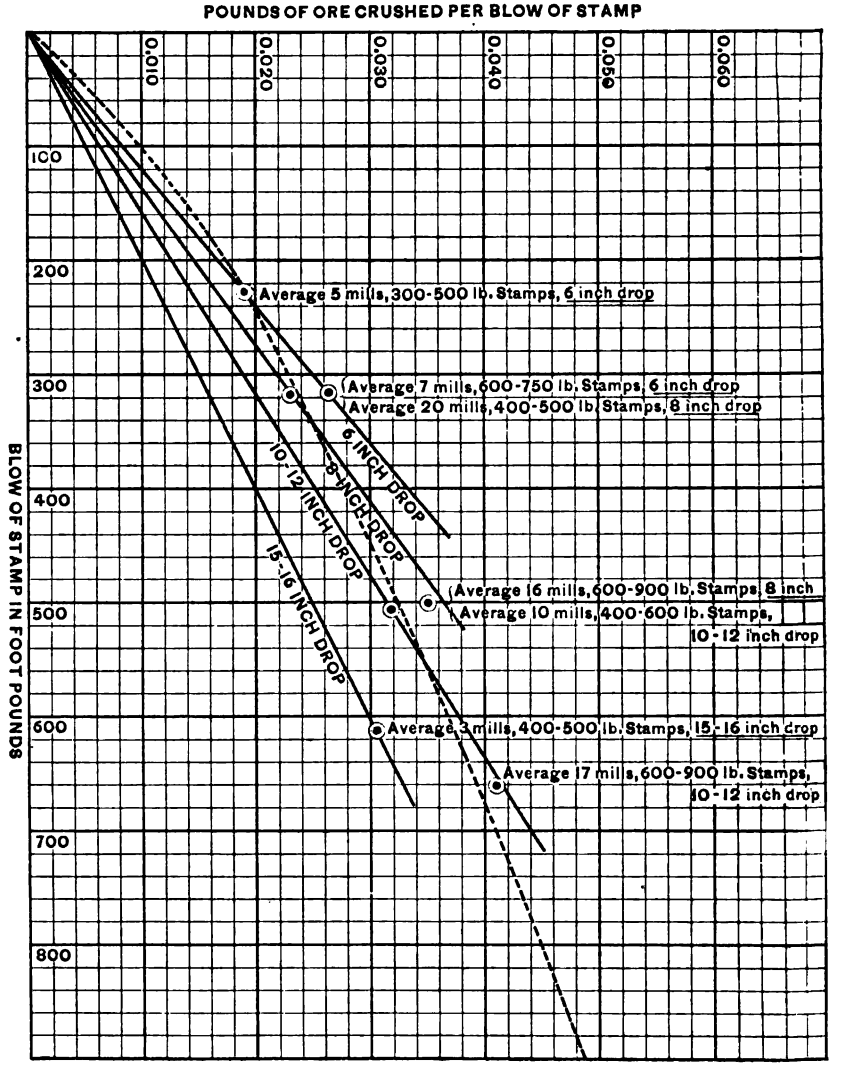
By comparing the figures given in column 6 of Table II, on p. 88, it will be seen that the efficiency of the Ball stamps per foot-pound is much less than that of stamps giving lighter blows, the Ball stamps crushing only about half as much per 1000 foot-pounds as the lighter stamps of the table. It seems probable, therefore, that there would be a gain in the use of lighter steam stamps. If it should be considered undesirable to increase the number of stamps in the mill, these light stamps, say one-half or one-third of the weight of those now in use, might be run at greater speed, or from 150 to 300 blows per minute. A stamp giving a blow of 10,000 foot-pounds, for example, would crush about 0.920 pounds of rock per blow, and by running it at the rate of 180 blows per minute its capacity would be the same as that of the average Ball stamp of the table. Per 1000 foot-pounds this stamp would crush 0.092 pounds of rock, a gain of 30 per cent. in efficiency over the heavy stamps now used. Again, a stamp giving a blow of 2500 foot-pounds would probably crush 0.305 pounds of rock per blow, or 0.122 pounds per 1000 foot-pounds exerted, a gain of 74 per cent. in efficiency over the heavy stamps now used. If it should prove, as seems probable, that such a light stamp can be run at 270 to 300 drops per minute without loss of effect per drop, then two of these stamps should do the work of one Ball stamp as now constructed.

HEIGHT OF LIFT.—It has thus been proved that the product of a stamp battery increases with the force of the blow of the stamps, though not quite in the same proportion. The tables already given show that it is the practice to increase the force of the blow by increasing both the weight of the stamp and the height of the drop, the heavier stamps having uniformly higher drops. It will be interesting, therefore, to compare stamps of different weight, having equal drop, in order to determine the effect of increase of weight, and also to compare stamps of equal foot-pounds but different drop, or light stamps with a high drop with heavy stamps with a low drop, in order to determine the effect of height of lift on the amount crushed per foot-pound. Diagram III gives the results of such a comparison. This comparison was made by grouping the Cali-

fornia stamp-mills, not only according to the weight of the stamps, but also according to height of drop, and then calculating the averages for each group as in the previous comparisons.

DIAGRAM III.

SHOWING THE EFFECT OF HEIGHT OF DROP ON THE CRUSHING CAPACITY OF THE STAMP.



The average of three Colorado mills with 15 and 16-inch drops has been added to show the effect of very high drops.

An inspection of Diagram III will show: first, that of stamps developing equal foot-pounds, those with a lower drop give decidedly better results than those with a higher drop; and second, that of stamps of equal drop, the lighter stamps give somewhat better results per foot-pound than the heavier ones.

We see, therefore, that both the increase of the weight of the stamps and the increase of the height of lift tend to diminish the amount of ore crushed per foot-pound, and that if it be necessary to increase the crushing effect of the battery it is better and more economical in the case of drop stamps to increase the weight of the stamp than the height of the drop.

This law does not apparently apply to velocity of impact, for the atmospheric stamp and the Ball steam stamp have a final velocity equal to that of a 2-foot drop and a 6-foot drop respectively. These stamps, with high velocity of impact, on the contrary, from inspection of the broken lines in Diagram II, would seem to give better results than the drop stamps with but 11 inches fall.

The explanation of the advantage of a low drop probably lies in the fact that the blow of the stamp is given under water, and that the resistance of the water and slime prevent the stamp from acquiring the velocity due to its fall, so that the stamp with a high drop expends a larger part of its energy in overcoming this resistance than is the case with the stamp with a low drop. The limit of economy in lessening the height of drop will be reached when the blow of the stamp barely produces the splash necessary to effect the discharge of the crushed ore through the screens.

Tables I and II show that but little change in the average height of drop was made in California between 1869 and 1875, except the abandonment of very high and very low drops. In 1869 the range was between 6 inches and 10 inches, but few mills only having drops of 11 and 12 inches. In 1875 eighty per cent. of the mills reported had drops of 7, 8, or 9 inches, while a few had 10 inches and above.

More recent data seem to indicate a tendency to adopt 8 inches as the standard height of drop. Diagram III would seem to indicate that 6 inches might be even better than 8 inches, but the results given in the diagram are drawn from too few mills to warrant the acceptance of this as proved.

It may be that the material crushed in these mills with low drops was soft ore, not requiring heavy blows.

In Colorado the change since 1869 has apparently been in a contrary direction. Of half a dozen mills visited this summer, representing the best practice in Gilpin County, the drop ranged from 13 inches to 18 inches, the average being 16 inches. The results obtained confirm the law already stated, the stamps with a low drop giving better results than those with a high drop. The necessity for a high drop in Colorado stamp batteries comes from the construction of the mortar, the bottom of the screens being 11 inches or more above the die. This high issue is given to allow the amalgamated copper plates in the mortar to be placed at least 6 inches above the die, that they may not be covered by slime nor have the amalgam rubbed off in the crushing of the ore. In short, the stamp batteries are built as amalgamating machines and not with a view to crush as much ore as possible.

SPEED OF STAMPS.—Tables I and II show that between 1869 and 1875 the average speed of stamps in California was increased from 62 drops per minute to 76 drops, an increase of 23 per cent. A careful inspection of Diagram II will show the average efficiency of the later stamp-mills to be as great as those of 1869. It is possible, however, that improvements in construction and in details of working may have offset losses due to extra speed. The following comparison, between mills of nearly equal foot-pounds and the same average height of drop, shows, however, no loss from 17 per cent. increase of speed.

	Foot-pounds.	Drops per minute.	Pounds crushed per blow.
Average 10 California mills,	525	82	0.034
Average 10 California mills,	534.7	70	0.035

The data are from the report for 1876, and therefore from mills of modern construction. The result would seem to show a slight advantage in favor of the slower-moving stamps; the difference, however, is exactly what should result from the difference in foot-pounds.

The high efficiency of the Phœnix atmospheric stamps, with 150 drops per minute, crushing .086 pounds of rock per drop, or 9.17 tons per head per twenty-four hours, furnishes another argument in favor of high speeds.

It would seem therefore that the speed of the stamp battery may be increased without diminishing the tons crushed per horse-power, the product of the battery increasing in the same proportion as the speed.

In dry stamping the effect of increasing the speed is to increase the product of the battery, and this in very much greater proportion. The following table, from the report of the Commissioner of Mining Statistics for 1870, gives the result of experiments made at the Mettacom Mill, of Austin, Nevada.

No. of drops per minute.	Horse-power, per stamp.	Increase of power.	Yield in tons, per 24 hours.	Increase of yield.
60	1.36		4½	
90	2.04	50 per ct.	10	122 per ct.
102	2.22	10 per ct.	15½	55 per ct.

By increasing the speed from 60 to 102 drops, an increase in speed of 70 per cent., the product of the battery was increased from 4½ to 15½ tons, or 244 per cent.

Effect of Size of Screen Openings and Area of Screens.—The discharge of the stamped material through the screens of the battery depends: first, on the size and total area of screen openings; second, on the average velocity of the jets of slime through the holes of the screen; and, finally, on the thickness of the slime or the proportion of solid material in the outflowing water. The larger the area of the screens the greater will be the discharging capacity of the battery.

The size of the screen openings has effect in several ways: first, the smaller the openings the finer the ore must be crushed, fine screens thus increasing the work of crushing and diminishing the crushing capacity of the battery; secondly, with fine openings the friction of their outflowing jets is increased, and therefore their velocity diminished; and, finally, the smaller the holes the less will be their total area in a screen of given size, since in order that the screen may be durable it is necessary to have the metal between the openings of greater proportional thickness. The effect of diminishing the size of the screen openings is, therefore, to diminish both the crushing and the discharging capacity of the battery. Rittinger, as the result of practical experiments, states that the product of a battery is proportional to $\sqrt[5]{d^2}$, d being equal to the diameter of the screen-openings.

The discharge of the slime will be mainly during the fall of the stamp, the suction produced in the lifting of the stamp-head having a tendency to retard or check the outflow. The velocity of the jets

of slime will be more or less proportional to the velocity of the falling stamps, and the duration of the jet will depend on the time occupied by the stamp in falling. The discharge of slime per blow of the stamp should, therefore, increase with increased drop of the stamp, the higher drop giving both greater velocity and longer time of falling. The total discharge in a given time should be proportional to the number of drops or splashes.

The thickness of the slime, that is, the amount of solid material in a given volume, will be greater the less water is used, and the longer the slime remains in the battery before being discharged. By increasing the height of issue, or by increasing the depth of mortar below the screen, we may increase the volume of slime in the mortar as compared with the volume of the outflow, and thus by lengthening the time in the mortar increase the thickness of the slime and diminish the amount of water required to effect the discharge of a certain amount of ore. In Colorado the amount of water required is from 0.33 to 0.5 cubic feet per head per minute. Rittinger attains a similar result, and at the same time utilizes the whole height of the screen for the discharge of the slime, by closing the front of the battery outside of the screen, and regulating the discharge by a spigot at the bottom. With this *stausatz* the amount of water required for fine stamping is 0.3 cubic feet per head per minute. The amount of water necessary to effect the discharge may thus be taken at 15 to 25 times the weight of the stamped material. By increasing in some such manner the thickness of the slime it is possible to increase the discharging capacity of the battery without enlarging the screen or the size of its openings, and at the same time to diminish the amount of water required. With the large amount of water used it is evident that the relative thickness or thinness of the slime will have little or no influence on the velocity of the outflowing jets.

It has frequently been stated by writers on the subject that the product of stamp-mills is limited by their discharging capacity; that it takes longer to effect the discharge of the ore through the screens than it does to crush it. In support of this statement an experiment is quoted, said to have been made in California some years ago. A quantity of pulp, which had already once passed through the battery, was recharged in the mortar, and it was found that it took nearly or quite as long for this material to pass through the screens as to crush an equal amount of ore. This, however, does not prove that the crushing capacity was any greater than the discharge, for in the

ordinary work of the battery the crushing and the discharge go on together.

If the crushing capacity of a battery exceeds the capacity of discharge then the product of the battery should be independent of the weight of the stamp. We have found, on the contrary, that the product increases with the weight of the stamp. Again, as a high drop gives longer duration and greater force to the splash, the product of stamps with a high drop should be greater than that of stamps with a low drop. We have found the contrary to be the case. Finally, the area of the screen should have important influence on the product in case the discharging capacity is less than the crushing capacity. The data at hand to decide this question are somewhat meagre. In the report for 1870 the dimensions of the screen are given in the case of twenty mills only. Grouping these mills according to weight and drop of stamps we find that mills with screens 12 inches wide give as good results as mills having 16-inch and 20-inch screens. A single mill is reported as having a screen of only 10 x 12 inches (!) for a battery of five stamps; and yet the product of this mill is as high as the average. The Colorado stamp-mills have screens only 9 or 10 inches wide, yet the product of these mills, when the drop is not too high, is as large as the average of the California mills. Finally, the Briggs Mill, in Black Hawk, Colo., has double discharge; the product, however, per blow of the stamp is not greater than the product of the Bobtail Mill, with screens on one side only. We may therefore reasonably infer that, with the ordinary dimensions of screen as used in California, the crushing capacity of the battery is not limited by the conditions of discharge. With soft material, ores of silver, for example, when the amount crushed per blow of the stamp is greater, it may be necessary to use larger screens, or even to employ a double discharge to the battery.

Other Conditions.—There are many other conditions affecting the product of a stamp battery for investigating which, unfortunately, we have no data. Among these are the ratio of the total area of the stamp shoes to the total area of the mortar, involving the effect on the product of the waste space in the mortar. Other questions connected with screen discharge demand investigation, including the best slope for screen plates, area necessary for a certain product, height of screens above mortar bottom, shape of screen openings, etc.

Résumé.—The following conclusions may be drawn from the data at hand:

1st. The product of a stamp battery, other things being equal, is

directly proportional to the foot-pounds developed in the fall of the stamp, and to the number of blows per minute, provided only that the discharging capacity of the battery be equal to or greater than its crushing capacity.

2d. Both the force of each blow and the number of blows per minute may apparently be increased up to certain limits with but slight diminution of the rock crushed per horse-power, provided that the discharge be increased in the same proportion.

3d. The discharge of a battery depends on the character of the screen (its area, the size and number of its openings, etc.), and on the number and duration of the splashes produced by the fall of the stamp. The discharge cannot therefore be increased indefinitely, but up to a certain limit increases in proportion to the speed of the battery or with the number of drops per minute.

4th. With a limited discharge, equal to or less than the crushing capacity of the battery, the product may be raised by increasing the speed but cannot be raised by increasing the force of the blow.

5th. A light stamp with a high drop and a heavy stamp with a low drop produce nearly equal crushing effect, provided that the foot-pounds developed are the same. The advantage, however, is in favor of the heavy stamp and low drop.

6th. To increase the crushing effect of a stamp battery it is better to increase the weight of the stamps than the height of the drops.

7th. A drop of 8 inches has been generally adopted as giving better results than higher drops. It is possible that still lower drops may prove economical.

8th. The objection to high drops does not seem to apply to high velocity of impact as obtained by spring stamps, atmospheric stamps, or steam stamps, which apparently give results as good as, or even better than those from stamps of which the foot-pounds are due principally to weight.

9th. High speed and high velocity of impact lessen the weight of the stamps and diminish the number of batteries requisite for a given amount of work, and therefore lessen the first cost of the plant. These smaller batteries do not demand large buildings for their accommodation, nor the construction of large and expensive foundations. To offset this saving must be placed the extra wear and tear due to high speeds.

10th. In the ordinary construction of stamp batteries with cams and tappets velocity of impact can be secured only by giving the stamps a high lift. This is incompatible with high speed. But as

we have already shown, under the conditions of limited discharge, speed is more to be desired than high velocity of impact.

11th. With steam stamps, atmospheric stamps, or spring stamps, both high velocity of impact and high speed can be secured. By the use of machines of this character the maximum effect can be obtained with the smallest plant. The product that can be obtained from one head will be limited by mechanical conditions, and by the impossibility of increasing the discharge beyond a certain limit. The last limitation will operate sooner with fine screens than with coarse.

12th. In fine stamping both the difficulty of discharge and the work of crushing increase with the fineness of the product. According to Rittinger the product of the stamp battery is proportional to $\sqrt[5]{d^2}$ in which d is the diameter of the screen openings. This ratio seems to hold good with the stamp mills of this country, though data are wanting to determine this exactly.

A GLOSSARY OF MINING AND METALLURGICAL TERMS.

BY R. W. RAYMOND, PH.D., NEW YORK.

THE absence of a convenient glossary of terms connected with mining and metallurgy has long been felt by the general public. It is to meet this want, not to furnish a technical manual for experts, that the following glossary has been prepared. It originated in an attempt on my part to revise for publication the manuscript of a compilation prepared from the appendix of Yale's work on *Mining Titles* and one or two other sources, to serve as an appendix to a new work on mining law, about to be published by Mr. H. N. Copp, of Washington, D. C. This revision soon assumed, contrary to my original intention, the proportions of a reconstruction; and with the consent of Mr. Copp, and for the purpose of receiving from my fellow-members valuable aid, I presented my still incomplete work as a paper at the Lake Superior meeting of the Institute, inviting from any quarter suggestions of new terms or better definitions to be incorporated in the glossary before its final publication. This invitation was so widely and generously responded to, that I cannot undertake to make in this place individual acknowledgments to those members of the Institute, and professional colleagues outside of it, who have favored me with assistance and advice. The labor bestowed upon this paper since its presentation at the Lake Superior meeting has considerably exceeded that of its first preparation, as

may be inferred from its great increase in length, as well as the numerous alterations which it has undergone. It could certainly be still further enlarged and improved; but I think a comparison of it with any of the glossaries of the same class now in print will show, at least, that it is an advance upon what has hitherto been accomplished. I shall be grateful, however, for further criticisms and suggestions; and I purpose at some future time to incorporate in a supplementary paper the results of such additional collections or corrections as I may obtain.

To avoid too great prolixity, I adopted at the outset the following general principles:

1. To include the most important technical words and phrases used by American miners and metallurgists, or occurring in English books and periodicals.

2. To exclude Spanish, French, and German terms, unless they fall under the rule above given. The Spanish terms included are in use among our miners in the far West and Southwest.

3. To exclude almost all purely scientific terms, such as those which denote the operations of chemical analysis, the chemical names and symbols of elements and compounds, the species of rocks and minerals, the principles of general physics and mechanics, etc.

4. To avoid scientific and technical explanations.

5. To omit, in general, self-explanatory terms, and such as are common to all mechanical and manufacturing trades.

The grounds of these rules are evident. It was neither practicable nor necessary to give in this paper what could be, and must be, sought in technical textbooks or general dictionaries and cyclopædias. But the paper as presented, and to a still higher degree as now completed, presents numerous exceptions to the above rules. Many geological terms, for instance, are so common among miners, and many chemical terms are so common among metallurgists as to render their adoption in this catalogue justifiable. The difficulty has been to "draw the line;" and this has been done, as I must confess, somewhat arbitrarily, and rather under the influence of a desire not to overburden the *Transactions* of the Institute than in consistent obedience to any rule.

An apology should be made for the obscurity of a few of the definitions. Many terms taken from English glossaries were found to be most vaguely defined; and in most cases of this kind, I was able to improve the definitions; but there remain some with which I was neither sufficiently acquainted to amend them with certainty,

nor sufficiently dissatisfied to strike them out altogether, nor sufficiently satisfied to let them stand without any explanation.

In many instances, the locality in which a term is believed to have originated or to be peculiarly in use, is indicated by abbreviations which will mostly explain themselves. The principal regions named are England, Scotland, Wales, France, Germany, the United States, Spain (including Mexico), Australia, Cornwall, Derbyshire, Staffordshire, Newcastle, Devonshire, Lake Superior, Pennsylvania, and the Pacific slope (including the mining districts of the Rocky Mountains). It must be understood that the naming, in this connection, of any one locality does not exclude the use of the term in other localities; and particularly that in this country the circulation both of miners and metallurgists, and of books and journals from all the world has brought into use a heterogeneous technical vocabulary. This is especially the case in the gold, silver, and lead mining districts of the West, where all the names, phrases, and theories that anybody anywhere at any time has cultivated, together with a crop of indigenous, spontaneous growth, seem to flourish vigorously.

GLOSSARY.

Abstrich, GERM. The black or greenish-brown mass (*black litharge*) appearing upon the bath of work-lead early in the cupelling-process, and gradually, as the process advances, giving way to pure litharge.

Abzug, GERM. The first scum appearing (before the *abstrich*) on the surface of molten lead.

Adit. A nearly horizontal passage from the surface, by which a mine is entered and unwatered. In the United States an adit is usually called a *tunnel*, though the latter, strictly speaking, passes entirely through a hill, and is open at both ends.

Adlings, ENG. Earnings.

Adobe, SP. Clay suitable for *adobes* or sun-dried bricks.

Adventurers, ENG. Shareholders or partners in a mining enterprise; in Cornwall, *cost-book* partners.

After-damp, ENG. The irrespirable gas, consisting of nitrogen and carbonic acid chiefly, remaining after an explosion of *fire-damp*.

Agitator, PAC. See *Settler*.

Aich's metal. See *Gun-metal.*

Air-head, or Air-heading, S. STAF. A smaller passage, driven parallel with the *gate-road*, and near its roof, to carry the ventilating current. It is connected with the *gate-road* at intervals by openings called *spouts*.

Air-reduction process. See *Roasting and Reaction process.*

Aitch-piece. See *H-piece.*

Alberti furnace. A continuously working reverberatory furnace for the roasting of quicksilver ores, with condensation of the mercury in iron-tubes and brick chambers.

Alligator. 1. See *Squeezer.* 2. A rock-breaker operating by jaws.

Alloy. A compound of two or more metals fused together.

Alluvium. The earthy deposit made by running streams, especially in times of flood.

Aludel. An earthen condenser for mercury. See *Bustamente furnace.*

Aluminium ores. *Cryolite,* a fluoride of sodium and aluminium, found in Greenland; *bauxite,* a hydrous compound of alumina, ferric oxide and silica.

Amalgamation. 1. The production of an amalgam or alloy of mercury. 2. The process in which gold and silver are extracted from pulverized ores by producing an amalgam, from which the mercury is afterwards expelled. See *Retorting.*

Amalgamator. 1. A machine for amalgamating ores. 2. The workmen in charge of such a machine.

American forge. See *Catalan forge.*

Anemometer. An instrument for measuring the rapidity of an air-current.

Annealing. 1. The gradual cooling of glass or metal from a high temperature, to render it less brittle. 2. See *Malleable castings.*

Anthracite. See *Coal.*

Anticlinal. The line of a crest, above or under ground, on the two sides of which the strata dip in opposite directions. The converse of *synclinal.*

Antimony ores. Native antimony; *stibnite* (sulphide of antimony); *valentinite* and *senarmontite* (oxides).

Apex. In the U.S. Revenue Statutes, the end or edge of a vein nearest the surface.

Apolvillados, SP. Ores superior in quality to the *azogues.*

Appolt oven. An oven for the manufacture of coke, differing from the *Belgian* in that it is divided into vertical compartments.

Aprons. See *Copper-plates.*

Arch, CORN. 1. A portion of a lode left standing when the rest is extracted, to support the *hanging wall* or because it is too poor for profitable extraction. 2. The roof of a reverberatory furnace.

Arenaceous. Silicious or sandy (of rocks).

Arends' tap. An arrangement by which the molten lead from the

crucible of a shaft-furnace is drawn through an "inverted siphon" into an exterior basin, from which it can be ladled without disturbing the furnace.

Arenillos, Sp. Refuse earth.

Argentiferous. Containing silver.

Argillaceous. Containing clay.

Arm. The inclined member or leg of a set or frame of timber.

Arrastre, Sp. Apparatus for grinding and mixing ores by means of a heavy stone dragged around upon a circular bed. The arrastre is chiefly used for ores containing free gold, and amalgamation is combined with the grinding. Sometimes incorrectly written *arraster*, *arrastra*, or *raster*.

Arroba, Sp. Twenty-five pound avoirdupois.

Arsenic ores. Native arsenic; *mispickel* (*arsenopyrite*, *arsenical pyrites*, arseno-sulphide of iron).

Ascension-theory. The theory that the matter filling fissure-veins was introduced in solution from below.

Ash-pit. The receptacle for ashes under a fire-place.

Assay. To test ores and minerals by chemical or blowpipe examination; said to be in *the dry way* when done by means of heat (as in a crucible), and in *the wet or humid way* when by means of solution and precipitation or liquid tests. An assay differs from a complete analysis in being confined to the determination of certain ingredients, the rest not being determined. Both assays and analyses may be either qualitative or quantitative; that is, they may determine the presence merely, or also the amount, of some or all of the constituents of the substance examined. The assay value of gold and silver ores is usually determined in Troy ounces (or, for gold, pennyweights) per ton (2000 pounds avoirdupois) of ore. See *Assay ton.* When reported in money value, the ounce of gold is taken at $20.6718. A ton of pure gold would be worth $602,928.51; the value of $6 per ton would be by weight one-thousandth per cent., and so on. Silver varies greatly in market value; but assayers often report their results according to the old U.S. standard, which made the ounce of pure silver worth $1.2929. The ton of silver at this rate, would be worth $37,710.40; the value of $37 per ton would be by weight one-tenth per cent., and so on. For ordinary gold and silver ores, it is evident that the percentages would be inconveniently small as expressions of value. Assays of lead, copper, iron, etc., are reported in percentages.

Assay-ton. A weight of 29.166⅔ grams. Since one ton of 2000 pounds avoirdupois contains 29.166⅔ troy ounces, it is evident that

each milligram of gold or silver obtained from one *assay-ton* of ore represents one ounce troy to the ton of 2000 pounds avoirdupois.

Assessment-work, PAC. The work done annually on a mining claim to maintain possessory title.

Astel. Overhead boarding or arching in a gallery.

Astyllen, ENG. A small dam in an adit or level, to check water.

Atierres, SP. Refuse ores.

Attle, CORN. Refuse rock.

Auger-nose shell. See *Wimble.*

Auger-stem. The bar to which a *drilling-bit* is attached.

Augèt or *Augètte.* A priming tube, used in blasting.

Augustin process. The treatment of silver ores by chloridizing, roasting, lixiviation with hot brine, and precipitation with copper.

Auriferous. Containing gold.

Average produce, CORN. The quantity of pure or fine copper in one hundred parts of ore.

Average standard, CORN. The price per ton of pure or fine copper in the ore.

Aviador, SP. A person who *habilitates* a mine; that is, who furnishes the money for working it by a contract with proprietors.

Azogueria, SP. 1. The amalgamating works. 2. The processs of amalgamation.

Azogues, SP. Common or inferior ores.

Back, CORN. 1. With reference to an adit, drift or stope, the part of the vein between it and the next working above, or the surface. 2. See *Face.*

Back-casing, ENG. A temporary shaft-lining of bricks laid dry, and supported at intervals upon *curbs.* When the *stone-head* has been reached, the permanent masonry lining is built upon it inside of the *back-casing.*

Back-end, NEWC. The part of a *judd* remaining after the *sump* has been removed.

Backing deals, NEWC. Planks driven vertically behind the curbs in a shaft from one curb to another.

Back-shift. The second set of miners working in any spot each day.

Back-skin, NEWC. A leather covering worn by men in wet workings.

Bait, NEWC. A pitman's provisions.

Bal, CORN. A mine.

Balance-bob. A heavy lever ballasted at one end, and attached

at the other to the pump-rod, the weight of which it thus helps to carry. When the shaft is deep, and the pump-rods are consequently very heavy, balance-bobs are put in at intervals of 200 or 300 feet, thus relieving the strain on the rods themselves and on the engine.

Balk, NEWC. A *hitch* producing a *nip*.

Balland, DERB. Pulverulent lead ore.

Ballast-shovel. A round-mouthed shovel.

Balling. The aggregation of iron in the *puddling* or the *bloomary* process into *balls* or *loups*.

Ball-stamp, LAKE SUP. A stamp for crushing rock, operated directly by steam-power, the stem of the stamp being at the same time the piston-rod of a steam cylinder.

Band, NEWC. Stone interstratified with coal.

Bank 1. (DERB. or *Benk*). The face of the coal at which miners are working. 2. An ore-deposit or coal-bed worked by surface excavations or drifts above water-level. 3. ENG. The ground at the top of a shaft. Ores are brought "to bank," *i. e.*, "to grass." See *Grass*.

Banksman, NEWC. See *Lander*.

Bar. 1. A drilling or tamping-rod. 2. A vein or dike crossing a lode. 3. A sand or rock ridge crossing the bed of a stream.

Bar-diggings, PAC. Gold-washing claims located on the bars (shallows) of a stream, and worked when the water is low, or otherwise with the aid of coffer-dams.

Barilla, SP. Native copper disseminated in grains in copper ores.

Barmaster, DERB. A mining official who collects the dues or royalties, presides over the *barmote*, etc. (From *Germ. Bergmeister*.)

Barmote, DERB. A mining court.

Barney. A small car attached to a rope and used to push cars up a slope or inclined plane.

Barranca, SP. A ravine.

Barrel. 1. The water-cylinder of a pump. 2. A piece of small pipe inserted in the end of a cartridge to carry the *squib* to the powder. 3. A vessel used in amalgamation.

Barrel-amalgamation. The amalgamation of silver ores by revolution in wooden barrels with quicksilver, metallic iron, and water.

Barrel-work, LAKE SUP. Native copper occurring in pieces of a size to be sorted out by hand in sufficient purity for smelting without mechanical concentration.

Barrier-pillars. *Pillars* of coal, larger than ordinary, left at in-

tervals to prevent too extensive crushing when the ground comes to be *robbed.*

Barrow, CORN. 1. A heap of *attle* or rubbish; a *dump.* 2. A vehicle in which ore, coal, etc., are wheeled.

Barrowmen, NEWC. See *Putters.*

Barrow-way, NEWC. A *level* through which coal or ore is wheeled.

Base bullion. See *Bullion.*

Base metals. The metals not classed as *noble* or precious. See *Noble metals.*

Basic. In furnace practice, a slag in which the earthy bases are in excess of the amount required to form a neutral slag with the silica present.

Basic lining. A lining for furnaces, converters, etc., formed of non-silicious material, usually limestone, dolomite, lime, magnesia, or iron oxide.

Basic-lining process. An improvement of the *Bessemer process,* in which, by the use of a basic lining in the *converter* and by the addition of basic materials during the *blow,* it is possible to eliminate phosphorus from the pig iron, and keep it out of the steel.

Basin. 1. A natural depression of strata containing a coal bed or other stratified deposit. 2. The deposit itself.

Bass or *batt.* See *Bind.*

Basset, DERB. An outcrop; the edge of a stratum.

Batch, CORN. The quantity of ore sent to the surface by a *pare* of men.

Batea, SP. A large wooden bowl in which gold-bearing earth or crushed ore is washed in the same way as in a *pan.*

Bath. A mass of molten material in a furnace, or of solution in a tank.

Batt. See *Bind.*

Battery. 1. A set of *stamps* in a stamp-mill, comprising the number which fall in one *mortar,* usually five. 2. A bulkhead of timber. 3. The plank closing the bottom of a *coal-chute.*

Battery-amalgamation. Amalgamation by means of mercury placed in the mortar.

Battery-assay. See *Pulp-assay.*

Bauxite. See *Aluminium-ores.*

Beans, NEWC. Small coals.

Bean-shot. Copper granulated by pouring into hot water.

Bear. 1. See *Salamander.* 2. See *Loup.*

Bearing. See *Strike.*

Bed. A seam or deposit of mineral, later in origin than the rock below, and older than the rock above; that is to say, a regular member of the series of formations, and not an intrusion.

Bedded vein. Properly *bed-vein* (*Lagergang* of the Germans); a lode occupying the position of a bed, that is, parallel with the stratification of the inclosing rocks.

Bede. A miner's pickaxe.

Bed-rock, PAC. The solid rock underlying alluvial and other surface formations.

Bed-way. An appearance of stratification, or parallel marking, in granite.

Beehive oven. An oven for the manufacture of coke, shaped like the old-fashioned beehive.

Belgian oven. A rectangular oven with end-doors and side-flues for the manufacture of coke.

Belgian zinc-furnace. A furnace in which zinc is reduced and distilled from calcined ores in tubular retorts.

Bell and hopper. See *Cup and cone.*

Belly-helve, ENG. A forge-hammer, lifted by a cam which acts about midway between the fulcrum and the head.

Bell-metal. A hard bronze, containing sometimes small proportions of iron, zinc, or lead, but ordinarily consisting of 78 parts copper to 22 tin.

Bell's dephosphorizing process. The removal of phosphorus from molten pig iron in a puddling furnace, lined with iron oxide and fitted with a mechanical rabble to agitate the bath. Red-hot iron ore is added. See *Krupp's washing process.*

Bench. 1. One of two or more divisions of a coal seam, separated by slate, etc., or simply separated by the process of cutting the coal, one bench or layer being cut before the adjacent one. 2. To cut the coal in *benches.*

Benching-up, NEWC. Working on the top of coal.

Bend or *Bind,* DERB. Indurated clay.

Beneficiar, SP. To benefit. To work or improve a mine; to reduce its ores; to derive profit or advantage from working it. *Beneficiation,* sometimes used in English, usually means the reduction of ores.

Bessemer iron. Pig iron suitable for the Bessemer process.

Bessemer process. The process of decarburizing a bath of molten cast iron by blowing air through it, in a vessel called a *converter.*

Biche. A tool ending below in a conical cavity, for recovering broken rods from a bore-hole.

Billet. 1. Iron or steel, drawn from a pile, bloom, or ingot into a small bar for further manufacture. 2. A small bloom.

Bind, DERB. See *Bend.*

Bing, NORTH ENG. Eight hundred weight of ore.

Bing-ore, DERB. Ore in lumps.

Bing-hole, DERB. A hole or *shoot* through which ore is thrown.

Bing-tale, NORTH ENG. See *Tribute.*

Bismuth-ores. Native bismuth; *bismuth ochre* (oxide); *bismuthine* (sulphide); also, bismuthiferous cobalt, silver and copper ores.

Bit. The cutting end of a boring implement.

Bituminous coal. See *Coal.*

Black-band. An earthy carbonate of iron, accompanying coal-beds. Extensively worked as an iron ore in Great Britain, and somewhat in Ohio.

Black-copper. Impure copper from smelting, before refining.

Black-damp, ENG. Carbonic acid gas.

Black-ends, ENG. Refuse coke from coking-ovens.

Black-flux. A mixture of charcoal and potassium carbonate.

Black-jack, CORN. Zinc-blende; sometimes hornblende.

Black-lead. Graphite.

Black litharge. See *Abstrich.*

Black-plate. Sheet iron before tinning.

Black-tin, CORN. Tin ore prepared for smelting.

Blair process. An improved form of the *Chenot process.*

Blanch. Lead ore, mixed with other minerals.

Blanched copper. An alloy of copper and arsenic.

Blanket-sluices. Sluices in which coarse blankets are laid, to catch the fine but heavy particles of gold, amalgam, etc., in the slime passing over them. The blankets are removed and washed from time to time, to obtain the precious metal.

Blast. 1. The operation of *blasting,* or rending rock or earth by means of explosions. 2. The air forced into a furnace to accelerate combustion. 3. The period during which a blast furnace is *in blast,* that is, in operation.

Blast furnace. A furnace, usually a shaft-furnace, into which air is forced under pressure.

Blasting-stick. A simple form of fuse.

Bleaching-clay, CORN. Kaolin, used with size, to whiten and give weight and substance to cotton goods.

Bleiberg furnace. See *Carinthian furnace.*

Blende. See *Zinc-ores.*

Blick, GERM. The *brightening* or iridescence appearing on silver or gold at the end of the cupelling or refining process.

Blind level. 1. A level not yet connected with other workings. 2. A level for drainage, having a shaft at either end, and acting as an inverted siphon.

Blind-shaft. See *Winze.*

Blister-steel. See *Steel.*

Bloat. A hammer swelled at the *eye.*

Block-coal, U. S. See *Coal.*

Block-furnace. See *Bloomary.*

Block tin. Cast tin.

Bloom. 1. A large steel bar, drawn from an ingot for further manufacture. 2. A rough bar of iron, drawn from a Catalan or bloomary ball, for further manufacture. See *Billet.*

Bloomary. A forge for making wrought-iron, usually direct from the ore. The sides are iron plates, the *hair-plate* at the back, the *cinder-plate* at the front, the *tuyere-plate* (through which the tuyere passes) at one side (its upper part being called in some bloomaries the *merrit-plate*) the *fore spar plate* opposite the *tuyere-plate* (its upper part being the *skew-plate*) and the *bottom-plate* at the bottom.

Blossom. The oxidized or decomposed outcrop of a vein or coal-bed, more frequently the latter. Also called *smut* and *tailing.* See *Gossan.*

Blow. A single *heat* or operation of the Bessemer *converter.*

Blower, NEWC. 1. A strong discharge of gas from a fissure. 2. A *fan* or other apparatus for forcing air into a furnace or mine.

Blow-george. A hand-fan.

Blow-in. To put a blast furnace in operation.

Blow-out. 1. To put a blast furnace out of blast, by ceasing to charge fresh materials, and continuing the blast until the contents of the furnace have been smelted. 2. A large outcrop, beneath which the vein is smaller, is called a *blow-out.* 3. A *shot* or blast is said to *blow out* when it goes off like a gun and does not shatter the rock.

Blowpipe. A tube through which air is forced into a flame, to direct it and increase its intensity. In the compound blowpipe, two jets of gas (one of which may be air) are united at the point of combustion.

Blue-billy, ENG. The residuum of cupreous pyrites after roasting with salt.

Blue-john, DERB. Fluorspar.

Blue lead. (Pronounced like the verb *to lead.*) The bluish auriferous gravel and cement deposit found in the ancient river-channels of California.

Blue metal. See *Metal.*

Blue peach, CORN. A slate-blue, very fine-grained schorl-rock.

Blue stone. Copper-vitriol; copper-sulphate.

Boards. The first set of excavations in *post-and-stall* work.

Boat level, WALES. A navigable *adit.*

Bob, CORN. A triangular frame, by means of which the horizontal motion imparted from an engine is transformed into a vertical motion of the pump-rods in a shaft.

Bob-station. See *Station.*

Bog-iron ore. A loose, earthy *brown hematite,* of recent origin, formed in swampy ground.

Boiling. See *Puddling,*

Bonanza, SP. Literally, fair weather. In miners' phrase, good luck, or a body of rich ore. A mine is *in bonanza* when it is profitably producing ore.

Bone. The slaty matter intercalated in coal-seams.

Bonnet. A covering over a cage to shield it from objects falling down the shaft.

Bonney, CORN. An isolated body of ore.

Booming. The accumulation and sudden discharge of a quantity of water (in placer mining, where water is scarce). See, also, *Hushing.*

Boot. A leather or tin joint connecting the *blast-main* with the *tuyère* or *nozzle* in a *bloomary.*

Bord, NEWC. A passage or *breast,* driven up the slope of the coal from the gangway, and hence across the *grain* of the coal.

Bord. See *Boards, Breast,* and *Post-and-stall.*

Board-and-pillar. See *Post and-stall.*

Borer. See *Drill.*

Borrasca, SP. The converse of *bonanza.* Barren rock.

Bort. Opaque black diamond.

Bosh. 1. A trough in which bloomary tools (or, in copper-smelting, hot ingots) are cooled. 2. (Or, *Boshes.*) The portion of a shaft furnace in which it widens from above the hearth up to its maximum diameter.

Bottom-lift. The deepest lift of a mining-pump, or the lowest pump.

Bottomer, ENG. The man stationed at the bottom of a shaft in charge of the proper loading of cages, signals for hoisting, etc.

Bottoms, CORN. 1. The deepest workings. 2. In copper-smelting, the impure metallic copper, or cupriferous alloy, which separates from the *matt*, and is found below it, when there is not enough sulphur present to retain in combination all the copper.

Boulder or *Bowlder*. A fragment of rock brought by natural means from a distance (though this notion of transportation from a distance is not always, in later usage, involved) and usually large and rounded in shape. *Cobble stones* taken from river-beds are, in some American localities, called boulders.

Bounds, CORN. A tract of tin-ore ground.

Bout, DERB. A measure of lead-ore; twenty-four *dishes*.

Bowke, S. STAFF. A small wooden box in which iron-ore is hauled underground.

Bowse or *Bouze*, DERB. Lead-ore as cut from the lode.

Box-bill. A tool used in deep boring for slipping over and recovering broken rods.

Box-groove. A closed groove between two *rolls*, formed by a collar on one roll, fitting between collars on another roll.

Box-timbering. See *Plank timbering*.

Brace, CORN. The mouth of a shaft.

Brace-head. A cross-attachment at the top of the column of rods in deep boring, by means of which the rods and bit are turned after each drop.

Brace-key. See *Brace-head*.

Braize, U. S. Charcoal-dust. See *Breeze*.

Brake-sieve. A *jigger*, operated by a hand-lever.

Brakesman. The man in charge of a winding-engine.

Brances. See *Brasses*.

Branch. CORN. A small vein departing from the main lode, and in some cases returning.

Basque. A lining for crucibles or furnaces; generally a compound of clay, etc., with charcoal-dust.

Brass. An alloy of copper and zinc.

Brasses, ENG. and WALES. Pyrites (sulphide of iron) in coal.

Brat, ENG. and WALES. A thin bed of coal mixed with pyrites or carbonate of lime.

Brattice, ENG., SCOT., and WALES. A plank lining, or a longitudinal partition of wood, brick, or even cloth, in a shaft, level, or gangway, generally to aid ventilation.

Brazil. Iron pyrites.

Breaker. See *Coal-breaker* and *Rock-breaker*.

Breast. 1. The *face* of a working. 2. In coal mines, the cham-

ber driven upwards from the *gangway*, on the seam, between pillars of coal left standing, for the extraction of coal. 3. That side of the *hearth* of a *shaft-furnace* which contains the *metal-notch*.

Breast-boards. Planking placed between the last set of timbers and the *face* of a *gangway* or *heading* which is in quicksand or loose ground.

Breccia. A *conglomerate* in which the fragments are angular.

Breeding-fire. See *Gob-fire.*

Breeze, ENG. Small coke. Probably connected, perhaps interchangeable, with *Braize*, and both with the FR. *Braise.*

Brettis, DERB. A *crib* of timber filled up with *slack* or waste.

Brettis-way. A road in a coal-mine, supported by *brettises* built on each side after the coal has been worked out.

Bridge. See *Reverberatory furnace.*

Bridle-chains. Safety-chains to support a *cage* if the link between the cage and rope should break.

Brightening. See *Blick.*

Broaching-bit. A tool used to restore the dimensions of a bore-hole which has been contracted by the swelling of the marl or clay walls.

Brob. A peculiar spike, driven alongside the end of an abutting timber to prevent its slipping.

Broil or *Broyl*, CORN. See *Bryle.*

Broken coal, PENN. See *Coal.*

Bronze. An alloy of copper and tin.

Brood, CORN. The heavier kinds of waste in tin and copper ores.

Brown coal. See *Coal.*

Browse. Ore imperfectly smelted, mixed with cinder and clay.

Brückner cylinder, PAC. A form of revolving roasting furnace.

Bryle, CORN. The traces of a vein, in loose matter, on or near the surface.

Bucker, DERB. A flat piece of iron with a wooden handle, used for breaking ore.

Bucket. The piston of a lifting-pump.

Bucking, DERB. See *Cobbing.* The *bucking-hammer* or *bucking-iron* is a broad-headed hammer used for this purpose; and the ore is broken on a flat piece of iron (*bucking-plate*).

Buckshot-cinder. Cinder from the iron blast-furnace, containing grains of iron.

Buckwheat-coal, PENN. See *Coal.*

Buddle, CORN. An inclined vat or stationary or revolving platform upon which ore is concentrated by means of running water.

Strictly the *buddle* is a shallow vat, not a platform or *table;* at least not in some localities. But general usage, particularly on the Pacific slope, makes no distinction.

Buggy. A small mine-wagon holding ½ ton to 1 ton of coal.

Buhrstone. A quartz rock containing cellules.

Buitron, SP. A furnace of peculiar construction, in which silver ore is reduced.

Bulkhead. 1. A tight partition or stopping in a mine for protection against water, fire, or gas. 2. The end of a flume, whence water is carried in iron pipes to hydraulic workings.

Bull. See *Clay-iron.*

Bulldog. 1. A refractory material used as furnace-lining, got by calcining *mill-cinder,* and containing silica and ferric oxide. 2. PENN. See *Buckshot-cinder.*

Bullfrog. See *Barney.*

Bullion. Uncoined gold and silver. *Base bullion* (PAC.), is pig lead containing silver and some gold, which are separated by refining.

Bull-pump, CORN. A direct single-acting pump, the steam cylinder of which is placed over the top of a shaft or slope, and the piston-rod attached to the pump-rods. The steam lifts piston and pump-rods, and the weight of these makes the down-stroke.

Bull-wheel. In rope-boring, a wheel on which is wound the rope for hoisting the bit, etc.

Bully. A pattern of miners' hammer, varying from "*broad-bully*" to "*narrow-bully.*"

Bunch of ore, CORN. An ore-body, usually a small one.

Bunding. A staging of boards on *stulls* or *stemples,* to carry *deads.* See *stull-covering.*

Buntons, ENG. Battens or scantlings placed horizontally across a shaft, to which are nailed the boards forming the *cleading* or *sheathing* of a *brattice.*

Burden, CORN. 1. The tops or heads of stream-work, which lie over the stream of tin. 2. The proportion of ore and flux to fuel in the charge of a blast-furnace.

Burning. See *Calcining.*

Burnt iron. 1. Iron which by long exposure to heat has suffered a change of structure and become brittle. It can be restored by careful forging at welding-heat. 2. In the *Bessemer* and *open-hearth* processes, iron which has been exposed to oxidation until all its carbon is gone, and oxide of iron has been formed in the mass.

Burr. Solid rock.

Burrow, CORN. A heap of refuse.

Buscones, SP. Searchers; explorers.

Bushel. The Imperial bushel, of 2218 cubic inches, and the Winchester bushel, of 2150 cubic inches, are divided into 4 pecks. The bushel used in measuring charcoal and coal contains 5 pecks, or 2680 cubic inches, being 20 pounds or less of charcoal, and, in various localities, 80, 76, or 72 pounds of coal.

Bustamente furnace. A cylindrical shaft-furnace for roasting quicksilver ores; divided by perforated arches into two compartments, of which the upper receives the ore and the lower the fuel. The mercury-vapors are condensed in *aludeln.*

Butt, ENG. Of coal; a surface exposed at right angles to the *face.* See *End.*

Button. The globule of metal remaining on an *assay-cupel* or in a crucible, at the end of the fusion.

Butty, DERB. and STAFF. A miner by contract at so much per ton of coal or ore.

Cabbling. Breaking up pieces of flat iron to be *piled* or *fagoted*, heated and rolled.

Cable-tools. The apparatus used in drilling deep holes, such as artesian wells, with a rope, instead of rods, to connect the drill with the machine on the surface.

Cache, FR. The place where provisions, ammunition, etc., are *cached* or hidden by trappers or prospectors in unsettled regions.

Cage. 1. A frame with one or more platforms for cars, used in hoisting in a vertical shaft. It is steadied by guides on the sides of the shaft. 2. A structure of elastic iron rods slipped into the bore-hole in *rod-boring* to prevent vibration of the rods. 3. The barrel or drum in a *whim* on which the rope is wound.

Cake-copper. See *Tough cake.*

Caking coal. See *Coal.*

Cala, SP. A small pit or experimental hole.

Cal, CORN. Wolfram.

Calcine. To expose to heat, with or without oxidation; to *roast.* Applied to ores for the removal of water and sulphur, and the disintegration of the mass; to limestone for the expulsion of its carbonic acid; etc.

Calciner. A furnace or kiln for roasting.

Calicata, SP. A digging or trial pit.

Campaign. The period during which a furnace is continuously in operation.

Cañada, SP. A ravine, or small cañon.

Canch. A part of a bed of stone worked by quarrying.

Cand or *Cann,* CORN. Fluorspar.

Cank, DERB. See *Whinstone.*

Cañon, SP. A valley, usually precipitous; a gorge.

Cannel coal. See *Coal.*

Cap or *Cap-rock.* Barren vein matter, or a *pinch* in a vein, supposed to overlie ore.

Capel. A composite stone of quartz, schorl, and hornblende.

Capella, SP. Cupelling furnace.

Captain, CORN. and WALES. The official in immediate charge of the work in a mine.

Carat. 1. A unit employed in weighing diamonds, and equal to $3\frac{1}{8}$ troy grains. A *carat-grain* is one-fourth of a carat. 2. A term employed to distinguish the fineness of a gold alloy, and meaning one-twenty-fourth. Fine gold is 24-*carat* gold. Goldsmiths' standard is 22 *carats* fine, *i. e.,* contains 22 parts gold, 1 copper, and 1 silver.

Carbona, CORN. An irregular deposit or impregnation of tin ore, found in connection with a tin lode.

Carbonaceous. Containing carbon not oxidized.

Carbonates. The common term in the West for ores containing a considerable proportion of carbonate of lead. They are sometimes earthy or ochreous (soft carbonates), sometimes granular and comparatively free from iron (sand carbonates), and sometimes compact (hard carbonates.) Often they are rich in silver.

Carbonization. The process of converting to carbon, by removing other ingredients, a substance containing carbon, as in the charring of wood or the natural formation of anthracite.

Carburization. The process of imparting carbon, as in making *cement steel.*

Carga, SP. A mule-load of 300 pounds avoirdupois.

Carinthian furnace. A small reverberatory with inclined hearth, in which lead ore is treated by *roasting and reaction,* wood being the usual fuel.

Car-wheel iron. See *Chill.*

Case. A small fissure, admitting water into the workings.

Case-harden. To convert iron superficially into steel by partial cementation.

Casing, CORN. 1. A partition or *brattice*, made of *casing-plank*, in a shaft. 2. PAC. *Casings* are zones of material altered by vein-action, and lying between the unaltered country rock and the vein.

Cast-after-cast, CORN. The throwing up of ore from one platform to another successively. See *Shambles*.

Cast-house. The building in which pigs or ingots are cast.

Casting. Pouring or drawing fused metal from a blast furnace, cupola, crucible, converter, or ladle into moulds.

Cast-iron. See *Iron*.

Cast-steel. See *Steel*.

Cata, SP. A mine denounced, but unworked.

Catalan forge. A forge with a tuyere for reducing iron ore, with charcoal, to a loup of wrought iron; a *bloomary*. See *Champlain forge*.

Cat-head. 1. A small capstan. 2. A *broad-bully* hammer. See *Bully*.

Cauf, NEWC. See *Corf*.

Caunter-lode, CORN. A vein coursing at a considerable angle to neighboring veins.

Caving. The falling in of the sides or top of excavations.

Cawk. Sulphate of baryta (heavy spar).

Cazo, SP. A caldron in which amalgamation is effected by the *cazo* process, used in Mexico and South America.

Cement, AUSTR. and PAC. Gravel firmly held in a silicious matrix, or the matrix itself.

Cementation. The process of producing a chemical change in a solid substance by packing it in a powder and heating it. See *Cement-steel* and *Malleable castings*.

Cement-copper. Copper precipitated from solution.

Cement-gold. Gold precipitated in fine particles from solution.

Cement-silver. Silver precipitated from solution, usually by copper.

Cement-steel. See *Steel*.

Cendrada, SP. Ashes or smeltings found at the bottom of a furnace, and valuable for use in other smeltings.

Cerro, SP. A hill or mountain.

Chacing. Following a vein by its range or direction.

Chafery. A forge fire for *reheating*. (From the FR. *Chaufferie*.)

Chaldron. Thirty-six bushels. In Newcastle fifty-three hundredweight avoirdupois. *Chaldron-wagons*, containing this quantity, convey the coal from the pit to the place of shipment.

Chalybeate. Impregnated with iron (applied to mineral waters).

Chamber. See *Breast.*

Champion lode. The main vein as distinguished from branches.

Champlain forge or *American forge.* A forge for the direct production of wrought iron, generally used in the United States instead of the Catalan forge, from which it differs in using only finely-crushed ore and in working continuously.

Changing-house, CORN. A room where miners change and dry their underground clothing. See *Dry.*

Charbon roux, FR. Brown charcoal, produced by an incomplete carbonization of wood.

Charge. 1. The materials introduced at one time or one round into a furnace. 2. The amount of explosive used for one blast.

Charger, CORN. An auger-like implement for charging horizontal bore-holes for blasting.

Charring. The expulsion by heat of the volatile constituents of wood, etc., leaving more or less pure vegetable carbon.

Chartermaster, S. STAFF. See *Butty.*

Chats, NORTHUMB. Small pieces of stone with ore.

Cheeks. 1. The sides or walls of a vein. 2. Extensions of the sides of the *eye* of a hammer or *pick.*

Chenot process. The process of making *iron-sponge* from ore mixed with coal-dust, and heated in vertical cylindrical retorts.

Chert. Hornstone; a silicious stone often found in limestone.

Cherry coal, ENG. See *Coal.*

Chestnut coal, PENN. See *Coal.*

Chilian Mill. An improved *arrastre,* in which a heavy stone wheel is rolled around the bed.

Chill. An iron mould or portion of a mould, serving to cool rapidly, and so to harden, the surface of molten iron which comes in contact with it. Iron which can be thus hardened to a considerable depth is *chilling iron,* and is specially used for cast-iron railway car-wheels requiring hardness at the rim without loss of strength in the wheel.

Chimming, CORN. See *Tossing.*

Chimney. An ore-shoot. See *Chute.*

China clay. Kaolin.

Chisel. See *Bit.*

Chock. See *Nog.*

Choke-damp, ENG. Carbonic acid gas.

Chlorides, PAC. A common term for ores containing chloride of silver.

Chloridize. To convert into chloride. Applied to the roasting of silver ores with salt, preparatory to amalgamation.

Chlorination process. The process first introduced by Plattner, in which auriferous ores are first roasted to oxidize the base metals, then saturated with chlorine gas, and finally treated with water, which removes the soluble terchloride of gold, to be subsequently precipitated and melted into bars.

Chrome ore. Chromic iron (*chromite*, oxide of chromium and oxide of iron).

Chute. (Sometimes written *shoot.*) 1. A channel or shaft underground, or an inclined trough above ground, through which ore falls or is "shot" by gravity from a higher to a lower level. 2. A body of ore, usually of elongated form, extending downward within a vein (*ore-shoot*). The two forms of orthography of this word are of French and English origin respectively. Under *chute*, the original idea is that of falling; under *shoot*, that of shooting or branching. Both are appropriate to the technical significations of the word. An *ore-shoot*, for instance, may be considered as a branch of the general mass of the ore in a deposit, or as a pitch or fall of ore (GERM. *Erz-fall*). In England the orthography *shoot* is, I believe, exclusively employed, and this is perhaps the best, the other being unnecessarily foreign.

Cinder, ENG. Slag, particularly from iron blast furnaces.

Cinder-pig, ENG. See *Pig iron.*

Cinder-plate. See *Bloomary.*

Cinder-tap, Cinder-notch. The hole through which cinder is tapped from a furnace. See *Liirmann front.*

Cinnabar. Sulphuret of mercury.

Cistern, CORN. See *Tank.*

Clack, CORN. A pump-valve.

Clack-door, CORN. An opening into the valve-chamber of a pump.

Claggy, NEWC. Adhesive. When the coal is tightly joined to the roof, the mine is said to have a *claggy top.*

Claim, PAC. The portion of mining ground held under the Federal and local laws by one claimant or association, by virtue of one location and record.

Clanny lamp. The safety-lamp invented by Dr. Clanny.

Clay-iron. A tool for crowding clay into leaky bore-holes.

Cleading, ENG. See *Buntons*.

Clean-up. The operation of collecting all the valuable product of a given period or operation in a stamp mill, or in a hydraulic or placer mine.

Cleat. 1. A joint in coal or rock. 2. A strip of wood.

Cleavage. The property in a mineral, of splitting more easily and perfectly in some directions than in others. The planes of cleavage bear a relation to the crystal form of the mineral. The *cleavage* of rock-masses is more properly a jointing, unless it follows the planes of bedding.

Clinker. The product of the fusion of the earthy impurities (ash) of coal during its combustion.

Clinometer. A simple apparatus for measuring by means of a pendulum or spirit-level and circular scale, vertical angles, particularly *dips*.

Clod. Soft shale or slate, in coal mines, usually applied to a layer forming a bad roof.

Closed top. See *Cup-and-cone*.

Closed front. An arrangement of the blast-furnace without a *forehearth*.

Clotting. The sintering or semi-fusion of ores during roasting.

Coal (ENG. *Coals*). This term is now applied to *stonecoal* or *pit-coal*, that is, mineral coal, obtained by mining, as distinguished from charcoal. No scientific account of the nature and origin of coal will be given here. The three principal classes recognized by common usage are *anthracite* (hard, black, composed, when pure, almost exclusively of carbon), *bituminous* or *coking coal* (brown or black, containing hydrocarbons), and *lignite* or *brown coal* (brown or black, generally showing a woody or a laminar structure, containing much water, and more recent, geologically speaking, than the other varieties). *Semi-anthracites* and *semi-bituminous coals* are gradations between *anthracite* and *bituminous*, based on the increasing percentage of volatile matters. *Hydrogenous* or *gas coals* are bituminous coals yielding the highest percentage of volatile matters. The English classification of *bituminous coals* distinguishes *coking coal* proper (splintering when heated, but subsequently fusing into a semi-pasty mass), *cherry* or *soft coal* (igniting readily and burning rapidly without splintering or fusion), *splint*, *rough* or *hard coal* (igniting with more difficulty but burning with a clear, hot fire), and *cannel coal* (the *parrot coal* of Scotland, compact, homogeneous, conchoidal in fracture, burning with clear, bright flame). The English call *an-*

thracite also *stonecoal* or *culm*, and speak of a *semi-anthracite* as *steam-coal*. Any coal advantageously used for generating steam is called a *steam-coal* in the United States. The solid carbon remaining after the expulsion of volatile matters from *bituminous coal* or *lignite* is called *coke*. Commercial *coke*, however, must have a certain coherence and strength; and the coals which furnish it in this condition are called *coking coals*. A peculiar bituminous coal of Indiana and Ohio, which breaks in blocks, and is used raw without coking, to some extent, as a blast-furnace fuel, is called *block-coal*. *Anthracite* is divided in the United States according to the color of the ash after burning, into *white-ash*, *red-ash*, and *pink-ash coal*. It is also classified for the market according to the size of the pieces (see *Coal-breaker*), as follows: *Lump* includes the largest lumps as they come from the mine. The other sizes pass over and through sieve-meshes of the size named, the figures signifying inches, and thus indicating roughly the average limit of diameter for the pieces in each size, viz.:

Steamboat,	through 7	over 4;
No. 1, *Broken* or *grate*,	through 4	over $2\frac{3}{4}$ to $2\frac{1}{2}$;
No. 2, *Egg*,	through $2\frac{3}{4}$ to $2\frac{1}{2}$	over $2\frac{1}{4}$ to 2;
No. 3, *Large stove*,	through $2\frac{1}{4}$ to 2	over $1\frac{7}{8}$ to $1\frac{1}{2}$;
No. 4, *Small stove*,	through $1\frac{7}{8}$ to $1\frac{1}{2}$	over $1\frac{1}{8}$ to 1;
No. 5, *Chestnut*,	through $1\frac{1}{8}$ to 1	over $\frac{5}{8}$ to $\frac{1}{2}$;
No. 6, *Pea*,	through $\frac{5}{8}$ to $\frac{1}{2}$	over $\frac{3}{8}$ to $\frac{1}{4}$.

No. 7, *Buckwheat*, is rarely made, except when the coal is washed on the screens, and the *chestnut* and *pea* have the larger dimensions above given. It is the smallest size, and usually included in the dirt or *culm*.

Coal-breaker. A building containing the machinery for breaking coal with toothed rolls, sizing it with sieves, and cleaning it for market.

Coal-pipes, NEWC. Very thin irregular layers of coal.

Cobalt-ores. *Cobalt-speiss* (*smaltine*, *chloanthite* when niccoliferous, *safflorite* when ferriferous, an arsenide of cobalt with or without nickel or iron); *cobalt glance* and *cobalt pyrites* (*smallite* and *linnæite*, sulphides of cobalt); *cobalt bloom* (*erythrite*, arseniate of cobalt).

Cobbing, CORN. Breaking ore to sort out its better portions. See *Spall*.

Cobble, PENN. An imperfectly puddled ball which goes to pieces in the *squeezer*.

Cobre ores. Copper ores from Cuba.

Cockle, CORN. See *Schorl.*

Cod, NEWC. The bearing of an axle.

Coffer or *Cofer*, DERB. 1. To secure a shaft from leaking by ramming in clay behind the masonry or timbering. 2. (or *Cover*) CORN. See *Mortar* (2). 3. A rectangular plank frame, used in timbering *levels.*

Coffin, CORN. 1. An old open working. 2. The mode of open working by casting up ore and waste from one platform to another, and so to the surface.

Cog. To roll or *bloom* ingots.

Cogs. See *Nogs;* only *cogs* are not squared, but simply notched where they cross each other. The interior of a structure of this kind and the spaces between the timber are usually filled with *gob.* They are called also *cobs*, *corncobs*, etc.

Coil-drag. A tool to pick up pebbles, bits of iron, etc., from the bottom of a drill-hole.

Coke. The product remaining after the expulsion by heat of the volatile constituents of coal.

Coking coal. See *Coal.*

Cold-bed. A platform in a rolling-mill on which cold bars are stored.

Cold blast. Air forced into a furnace without being previously heated.

Cold-short. Brittle when cold. Applied chiefly to iron and steel.

Collar. 1. See *Cap.* 2. The *collar* of a shaft is the horizontal timbering around the mouth.

Colliery. A coal mine.

Collom washer, LAKE SUP. A variety of *jig.*

Color, SP. 1. Color. The shade or tint of the earth or rock which indicates ore. 2. A particle of metallic gold found in the prospector's pan after a sample of earth or crushed rock has been "panned out." Prospectors say, *e. g.*, "The dirt gave me so many colors to the panful."

Colorados, SP. Ores impregnated with oxide of iron, and in a state of decomposition. See *Gossan.*

Col-rake. A shovel used to stir lead-ores during washing.

Comb. The place, in a fissure which has been filled by successive depositions of mineral on the walls, where the two sets of layers thus deposited approach most nearly or meet, closing the fissure and exhibiting either a drusy central cavity, or an interlocking of crystals.

Combined carbon. That portion of the carbon in iron or steel which is not visible as graphite, and is supposed to be alloyed or chemically combined with the iron.

Compass. An instrument like the ordinary nautical or surveyor's compass, though sometimes otherwise marked, and having a *clinometer* attached. Also, a *dip-compass*, for tracing magnetic iron ore, having a needle hung to move in a vertical plane.

Concentration. The removal by mechanical means of the lighter and less valuable portions of ore.

Concentrator. An apparatus in which, by the aid of water or air and specific gravity, mechanical concentration of ores is performed.

Condenser. A vessel or chamber in which volatile products of roasting or smelting (*e. g.*, mercury or zinc vapors) are reduced to solid form by cooling, or in which the fumes of furnaces, containing mechanically suspended as well as volatile metallic matters, are arrested.

Conglomerate. A rock consisting of fragments of other rocks (usually rounded) cemented together.

Consume. The chemical and mechanical loss of mercury in amalgamation.

Contact. The plane between two adjacent bodies of dissimilar rock. A *contact-vein* is a vein, and a *contact-bed* is a bed, lying, the former more or less closely, the latter absolutely, along a contact.

Continental process. See *German process.*

Converter. See *Bessemer process.*

Cope. 1. DERB. To contract to mine lead ore by the *dish*, load, or other measure. 2. The upper part of a *flask*, separable from the lower part. See *Drag.*

Coper, DERB. One who contracts to raise lead-ore at a fixed rate.

Copperas. Ferrous sulphate.

Copper-ores. Native copper; red copper-ore (*cuprite*, protoxide); green and blue *malachite* (*malachite* and *azurite*, carbonates); *copper glance* (*chalcocite*, sulphide); *purple copper* (variegated or *peacock* ore, *bornite*, sulphide of copper and iron); *gray copper* (*fahl-ore*, *tetrahedrite*, sulphantimonide of copper and other metals); *yellow copper* (*copper-pyrites*, *chalcopyrite*, sulphide of copper and iron); *copper-lead ore* (*bournonite*, sulphantimonide of lead and copper); *black copper-ore* (an earthy and variable mixture of sulphide and oxide of copper).

Copper-plates, AUSTR. and PAC. The plates of amalgamated copper

over which the auriferous ore is allowed to flow from the stamp battery, and upon which the gold is caught as amalgam.

Copper-rain. Minute globules thrown up from the surface of molten copper, when it contains but little suboxide.

Copper-smoke. The gases from the calcination of sulphuretted copper-ores.

Corbond. An irregular mass or "dropper" from a lode.

Cordurié process. The refining of lead by conducting steam through it, while molten, to oxidize certain metallic impurities.

Core, CORN. A miner's underground working-time or *shift.*

Corf, Corve, or *Cauf* (the last incorrect). 1. NEWC. A large basket used in hoisting coal; from the GERM. *Korb.* 2. A wooden frame to carry coal. 3. A sled or low wagon for the same purpose.

Cornish pump. A pump operated by rods attached to the beam of a single-acting, condensing beam-engine. The steam, pressing down the piston in the vertical steam-cylinder, lifts the pump-rods, and these subsequently descend by their own weight.

Coro-coro. A dressed product of copper-works in South America, consisting of grains of native copper mixed with pyrite, chalco-pyrite, mispickel, and earthy minerals.

Corroding-lead. Refined lead, sufficiently pure for the corroding process, by which white lead is manufactured.

Cost-book, CORN. A book used to keep accounts of mining enterprises carried on under the *cost-book system,* peculiar to Cornwall and Devon, and differing from both partnership and incorporation. It resembles the mining partnership system of the Pacific States.

Costeaning or *Costeening,* CORN. Discovering veins by pits and open cuts, run on the surface transversely to the supposed course of the veins.

Counter. 1. A cross-vein. 2. (Or *counter-gangway.*) A gangway driven obliquely upwards on a coal-seam from the main gangway until it cuts off the faces of the workings, and then continues parallel with the main gangway. The oblique portion is called the *run.*

Country, or *country-rock,* CORN. The rock traversed by or adjacent to an ore deposit.

Course. See *Strike.*

Course of ore. See *Chute* (2.).

Coursing. Conducting the air-current of a mine in different directions by means of doors and stoppings.

Cousin Jack. A common nickname for a Cornishman.

Covered-binding, CORN. See *Plank-timbering.*

Cow. A kind of self-acting brake for inclined planes; a trailer.

Cowl. See *Water-barrel.*

Cowper-Siemens stove. A hot-blast stove of firebrick on the regenerative-principle.

Coyoting, PAC. Mining in irregular openings or burrows, comparable to the holes of *coyotes* or prairie foxes.

Crab. A machine for moving heavy weights. Specially the engines employed for lowering into place the pumps, rods, pipes, etc., of Cornish *pit-work.*

Cradle, PAC. See *Rocker.*

Cramp. A pillar of rock or mineral left for support.

Cranch. Part of a vein left by old workers.

Craze or *Creaze*, CORN. The tin-ore which collects in the middle part of the *buddle.*

Creep, NEWC. A rising of the floor of a gangway, occasioned by the weight of incumbent strata, in pillar workings. Also any slow movement of mining ground.

Cretaceous. 1. Chalky. 2. See *Geological formations.*

Crevet. A crucible.

Crevice, PAC. 1. A shallow fissure in the bed-rock under a gold placer, in which small but highly concentrated deposits of gold are found. 2. The fissure containing a vein.

Crib. 1. See *Curb.* 2. A structure composed of frames of timber laid horizontally upon one another, or of timbers built up as in the walls of a log-cabin. 3. A miner's luncheon.

Cribbing. Close timbering, as the lining of a shaft, or the construction of *cribs* of timber or timber and earth or rock, to support a roof.

Cribble. A sieve.

Crop. 1. CORN. See *Crop-tin.* 2. The *basset* or *outcrop* of strata at the surface. 3. To leave coal at the bottom of a bed.

Cropping out. The rising of layers of rock to the surface. That part of a vein which appears above the surface is called the *cropping* or *outcrop.*

Crop-tin. The chief portion of tin-ore separated from waste in the principal dressing operation.

Cross-course, CORN. An intersecting (usually a barren) vein.

Cross-cut. A level driven across the course of a vein, or, in general, across the direction of the main workings (as to connect two parallel gangways), or across the "grain of coal."

Cross-heading. A heading driven across from one gangway or breast to another, usually for ventilation.

Cross-vein. An intersecting vein.

Crow or *crow-foot.* A tool with a side-claw, for grasping and recovering broken rods in deep bore-holes.

Crucible. 1. A melting pot. 2. The lower part of a shaft furnace, in which fusion is effected and the molten bath is contained.

Crush. 1. A *squeeze*, accompanied, perhaps, with more violent motion and effects. 2. A variety of fault in coal. See *Fault* (2).

Crusher. A machine for crushing ores.

Cry of tin. The peculiar crackling noise produced in bending a piece of metallic tin.

Culm. 1. ENG. Anthracite. 2. PENN. The waste or *slack* of the Pennsylvania anthracite mines, consisting of fine coal, more or less pure, and coal-dust and dirt.

Cup-and-cone. A machine for charging a shaft-furnace, consisting of an iron hopper with a large central opening, which is closed by a *cone* or *bell*, pulled up into it from below. In the annular space around this cone, the ore, fuel, etc., are placed; then the cone is lowered to drop the materials into the furnace; after which it is again raised to close the hole.

Cupellation. The treatment on a hearth or *cupel* (usually formed of bone-ash) of an alloy of lead, gold, and silver, by means of fusion and an air blast, which oxidizes the lead to litharge, and removes it in liquid form, or absorbs it in the cupel.

Cupola. A shaft-furnace with a blast, for remelting metals, preparatory to casting. Sometimes incorrectly pronounced and written *Cupalo.*

Curb. A timber frame, circular or square, wedged in a shaft to make a foundation for walling or tubbing, or to support, with or without other timbering, the walls of the shaft.

Curbing. See *Cribbing.*

Cut. 1. To intersect a vein or working. 2. To excavate coal.

Dam. 1. To keep back water in a stream or mine by means of a dam or bulkhead. 2. S. STAFF. See *Stopping* and *Bulkhead.* 3. The wall of refractory material, forming the front of the *fore-hearth* of a blast furnace. It is built on the inside of a supporting iron plate (*dam-plate*). Iron is tapped through a hole in the dam, and cinder through a notch in the top of the dam. See *Lürmann front.*

can be held by a valid title. The opening in which it is made is called *discovery-shaft*, *discovery-tunnel*, etc.

Dish, CORN. 1. The landowner's or landlord's part of the ore. 2. DERB. A measure of 14, 15, or 16 pints.

Dissuing, CORN. Cutting out the *selvage* or *gouge* of a lode, to facilitate the ore-extraction.

Distillation. Volatilization, followed by condensation to the liquid state.

District. In the States and Territories west of the Missouri, a vaguely bounded and temporary division and organization made by the inhabitants of a mining region. A district has one code of mining laws, and one recorder. Counties and county officers are gradually taking the place of these cruder arrangements.

Ditch. An artificial watercourse, flume, or canal, to convey water for mining. A flume is usually of wood; a ditch, of earth.

Divining-rod or *Dowsing-rod*, CORN. A rod (most frequently of witch-hazel, and forked in shape) used, according to an old but still extant superstition, for discovering mineral veins and springs of water, and even for locating oil wells.

Doggy, S. STAFF. An underground superintendent, employed by the *butty*.

Dog-hole.. A small *proving-hole* or airway, usually less than 5 feet high.

Dole. A division of a parcel of ore.

Dolly-tub, CORN. A tub in which ore is washed, being agitated by a *dolly*, or perforated board.

Dope. See *Explosives.*

Dotts or *Dott-holes.* Small openings in the vein.

Douglas process. See *Hunt and Douglas process.*

Downcast. The opening through which the ventilating air-current descends into a mine.

Downcome. The pipe through which *tunnel-head* gases from iron blast-furnaces are brought down to the hot-blast stoves and boilers, when these are below the *tunnel-head.*

Dradge, CORN. The inferior portions of ore, separated from the *prill* by cobbing.

Drag. The lower part of a *flask.* The mould having been prepared in the two parts of the flask, the *cope* is put upon the *drag* before casting. After casting, the flask is opened by removing the *cope.*

Drag-twist. A spiral hook at the end of a rod, for cleaning bore-holes.

Draught, S. STAFF. The quantity of coal raised *to bank* in a given time.

Draw. To *rob* pillars or the top-coal of breasts before abandoning the ground.

Dredge. Very fine mineral matter held in suspension in water.

Dresser, S. STAFF. A large pick, with which the largest lumps of coal are prepared for loading into the *skip.*

Dressing, CORN. The picking and sorting of ores, and washing, preparatory to reduction.

Drift. 1. A horizontal passage underground. A *drift* follows the vein, as distinguished from a *cross-cut,* which intersects it, or a *level* or *gallery,* which may do either. 2. Unstratified *diluvium.*

Drill. A metallic tool for boring in hard material. The ordinary miner's drill is a bar of steel, with a chisel-shaped end, and is struck with a hammer. See *Rock-drill, Diamond-drill.*

Driving. Extending excavations horizontally. Distinguished from *sinking* and *raising.*

Dropper, CORN. A branch leaving the main vein on the *footwall* side.

Dross. The material skimmed from the surface of freshly melted, not perfectly pure metal.

Drowned level. See *Blind level,* (2).

Druggon, S. STAFF. A square iron or wooden box, used for conveying fresh water for horses, etc., in a mine.

Drum. That part of the winding machinery on which the rope or chain is coiled.

Druse. A crystallized crust lining the sides of a cavity.

Dry, CORN. See *Changing-house.*

Dry copper. See *Under-poled copper.* Also copper just ready for *poling.*

Dry Puddling. See *Puddling.*

Dry sand. Sand prepared for *moulds* by thorough drying and baking. When special cohesion is required (as for *cores*) other substances, such as flour, molasses, etc., are mixed with it.

Dualin. See *Explosives.*

Dumb-drift. An *air-way* conveying air around, not through, a ventilating furnace to the *upcast.*

Dump. 1. To unload a vehicle by tilting or otherwise, without handling or shovelling out its contents. 2. A pile of ore or rock.

Dumper. A tilting-car used on *dumps.*

Durn, CORN. A frame of timbering, like a door-frame.

Dust-plate. A vertical iron plate, supporting the *slag-runner* of an iron blast furnace.

Dutch metal. An alloy of copper and zinc, containing more copper than ordinary brass.

Duty. A measure of the effectiveness of a steam-engine, usually expressed in the number of foot-pounds (or kilogrammetres) of useful work obtained from a given quantity of fuel.

Duty-ore, CORN. The landlord's share of the ore.

Dyke. See *Dike.*

Dzhu, CORN. To cut ahead on one side of a *face,* so as to increase the efficacy of blasting on the remainder. (Doubtless the same word as *Dissue.* See *Dissuing.*) Also called *to hulk.*

Egg-coal, PENN. See *Coal.*

Egg-hole, DERB. A notch cut in the wall of a lode to hold the end of a *stempel.*

Electrum. An alloy of copper, zinc, and nickel.

Eliquation. Separating an alloy by heating it so as to melt the more fusible of its ingredients, but not the less fusible.

Elutriation. Purification by washing and pouring off the lighter matter suspended in water, leaving the heavier portions behind.

Elvan, CORN. A name given to certain broad granite veins or belts in schistose rocks.

Emery. Impure corundum.

End of coal. The direction or section at right-angles to the *face;* sometimes called the *butt.*

End-pieces, CORN. See *Wall-plates.*

English process. In copper-smelting, the process of *reduction* in a *reverberatory* furnace, after *roasting,* if necessary.

English zinc-furnace. A furnace in which zinc is reduced and distilled from *calcined* ores in *crucibles.*

Engorgement. The *clogging* of a furnace. See *Scaffold.*

Entry. An *adit.* Applied to the main *gangway* in some coal mines.

Estufa amalgamation, SP. A modification of the *patio* process, using heat.

Exploder. A cap or fulminating cartridge, placed in a charge of gunpowder or other explosive, and exploded by electricity or by a fuse. See *Explosives.*

Exploitation, FR. The productive working of a mine, as distinguished from exploration.

Explosives. The principal explosives used in mining are *gunpowder*, a compound of sulphur, charcoal, and potassium nitrate (potash saltpetre) or sodium nitrate (Chili or soda-saltpetre); *nitroglycerin*, a liquid compound of carbon, hydrogen, nitrogen, and oxygen, produced by the action of nitric acid upon glycerin; *dynamite No.* 1, or *giant-powder*, a mixture of nitroglycerin with a dry pulverized mineral or vegetable absorbent or *dope* (commonly silicious or infusorial earth); *dynamite No.* 2, nitroglycerin mixed with saltpetre, sawdust, or coaldust, paraffin, etc., in lieu of an inexplosive *dope; lithofracteur*, nitroglycerin mixed with silicious earth, charcoal, sodium (and sometimes barium) nitrate and sulphur; *dualin*, nitroglycerin, mixed with potassium nitrate and fine sawdust; *rend-rock, Hercules, Neptune, tonite, vigorite*, and other powders, resembling dynamite No. 2, *i. e.*, consisting of nitroglycerin with a more or less explosive *dope;* and *mica-powder*, a No. 1 *dynamite*, in which the *dope* is fine scales of mica. The *chlorate, picrate*, and *fulminate* explosives are not used in mining, except the fulminate of mercury, which is employed for the *caps* or *exploders*, by means of which charges of powder, dynamite, etc., are fired.

Eye. 1. The top of a shaft. 2. The opening at the end of a *tuyere*, opposite the *nozzle*. 3. The hole in a *pick* or hammer-head which receives the handle.

Face. 1. In any adit, tunnel, or stope, the end at which work is progressing or was last done. 2. The *face of coal* is the principal cleavage-plane at right angles to the stratification. Driving *on the face* is driving against or at right angles with the face.

Fagot. See *Pile.*

Fahlband, GERM. A zone or stratum in crystalline rock, impregnated with metallic sulphides. Intersecting fissure-veins are enriched by the *fahlband.*

Famp, NEWC. Soft, tough, thin shale beds.

Fan. A revolving machine, to blow air into a mine (*pressure-fan, blower*), or to draw it out (*suction-fan*).

Fanega, SP. A bushel; sometimes half a mule-load.

Fang, DERB. An air-course cut in the side of a shaft or level, or constructed of wood.

Fast-end. 1. The part of the coal-bed next the rock. 2. A gangway with rock on both sides. See *Loose-end.*

Fast shot, NEWC. A charge of powder exploding without the desired effect.

Fathom, CORN. Six feet. A *fathom of mining ground* is six feet square by the whole thickness of the vein, or in Cornish phrase, *a fathom forward by a fathom vertical.*

Fauld. The *tymp-arch* or working-arch of a furnace.

Fathom-tale, CORN. See *Tut-work* (2). This name probably arises from the payment for such work by the space excavated, and not by the ore produced.

Fault. 1. A dislocation of the strata or the vein. 2. In coal-seams, sometimes applied to the coal rendered worthless by its condition in the seam (*slate-fault, dirt-fault*, etc.).

Feather. See *Plug and feather.*

Feathered-shot. Copper granulated by pouring into cold water.

Feathering. See *Plugging.*

Feeder. 1. A small vein joining a larger vein. 2. A spring or stream. 3. A *blower* of gas.

Feigh, NEWC. Refuse washed from lead-ore or coal.

Feldspathic. Containing feldspar as a principal ingredient.

Fell. See *Riddle.*

Ferrie furnace. A high iron blast furnace, in the upper part of which crude bituminous coal is converted into coke.

Ferromanganese. An alloy of iron and manganese.

Ferruginous. Containing iron.

Fettle, Fettling. See *Fix.*

Fillet. The rounded corner of a *groove* in a *roll.*

Fin. The thin sheet of metal squeezed out between the collars of the *rolls* in a *roll-train.*

Fine metal. 1. See *Metal.* 2. The iron or plate-metal produced in the *refinery.*

Finery. A charcoal-hearth for the conversion of cast into malleable iron.

Fining. 1. See *Refining.* 2. The conversion of cast into malleable iron in a hearth or charcoal-fire.

Finishing-rolls. The *rolls* of a *train* which receive the bar from the *roughing-rolls*, and reduce it to its finished shape.

Fire-bars. Grate-bars in a fireplace.

Fire-bricks. Refractory bricks of fire-clay or of silicious material used to line furnaces.

Fire-bridge. The separating low wall between the fire-place and the *hearth* of a reverberatory furnace.

Fire-clay. A clay comparatively free from iron and alkalies, not easily fusible, and hence used for fire-bricks. It is often found beneath coal-beds.

Fire-damp. Light carburetted hydrogen gas. When present in common air to the extent of one-fifteenth to one-thirteenth by volume, the mixture is explosive.

Fire-setting. The softening or cracking of the working-face of a lode, to facilitate excavation, by exposing it to the action of a wood-fire built close against it. Now nearly obsolete, but much used in hard rock before the introduction of explosives.

Fire-stink, S. STAFF. The stench from decomposing iron pyrites, caused by the formation of sulphuretted hydrogen.

Fissure-vein. A fissure in the earth's crust filled with mineral.

Fix. To *fettle* or line with a *fix* or *fettling,* consisting of ores, scrap and cinder, or other suitable substances, the hearth of a puddling furnace.

Flang, CORN. A two-pointed miner's pick.

Flange. Applied to a vein widening.

Flap-door, NEWC. A manhole door.

Flask. 1. The wooden or iron frame which holds the sand-mould used in a foundry. 2. An iron bottle in which quicksilver is sent to market. It contains 76½ pounds.

Flat, DERB. and N. WALES. A horizontal vein or ore-deposit auxiliary to a main vein; also any horizontal portion of a vein elsewhere not horizontal.

Flat-nose shell. A cylindrical tool with valve at bottom, for boring through soft clay.

Flat-rods. A series of horizontal or inclined connecting-rods, running upon rollers, or supported at their joints by rocking-arms, to convey motion from a steam-engine or water-wheel to pump-rods at a distance.

Flat-wall, CORN. A local term (in St. Just) for *foot-wall.*

Flintshire furnace. A *reverberatory* with a depression, *well* or *crucible* in the middle of the side of the hearth; used for the *roasting and reaction process* on lead ores.

Float-copper, LAKE SUP. Fine scales of metallic copper (especially produced by abrasion in stamping) which do not readily settle in water.

Float-gold, PAC. Fine particles of gold, which do not readily settle in water, and hence are liable to be lost in the ordinary stamp-mill process.

Float-ore. Water-worn particles of ore; fragments of vein-material found on the surface, away from the vein-outcrop.

Flookan or *Flooking*, CORN. See *Fluccan.*

Floor. 1. The rock underlying a stratified or nearly horizontal deposit, corresponding to the *foot-wall* of more steeply-dipping deposits. 2. A horizontal, flat ore-body. 3. A floor, in the ordinary sense, or a plank platform underground.

Floran-tin, CORN. Tin ore scarcely visible in the stone, or stamped very small.

Flosh, CORN. A rude mortar, with a shutter instead of a screen, used under stamps.

Floss. Fluid, vitreous cinder, floating in a puddling furnace.

Floss-hole. A tap-hole.

Floured. The finely granulated condition of quicksilver, produced to a greater or less extent by its agitation during the amalgamation process.

Flowing furnace. A *reverberatory* with inclined hearth, used in Cornwall for treating roasted lead ores by the *precipitation process.*

Fluccan, CORN. Soft clayey matter in the vein; a vein or course of clay.

Flue. A passage for air, gas, or smoke.

Flue-bridge. The separating low wall between the flues and the laboratory of a reverberatory furnace.

Flue-cinder. Iron-cinder from the reheating furnace, so called because it runs out from the lower part of the flue.

Flume. A wooden conduit, bringing water to a mill or mine.

Flux. A salt or other mineral, added in smelting to assist fusion, by forming more fusible compounds.

Foal, NEWC. A young boy employed in *putting* coal.

Fodder, NORTH ENG. A unit employed in expressing weights of metallic lead, and equal to 21 hundredweight of 112 pounds avoirdupois.

Foge, CORN. A forge for smelting tin.

Fondon. A large copper vessel, in which hot amalgamation is practiced.

Foot-piece. See *Sill.*

Foot-wall, CORN. The wall under the vein.

Foot-way. The series of ladders and *sollars* by which men enter or leave a mine.

Forefield, NEWC. The face of the workings. The *forefield-end* is the end of the workings farthest advanced.

Fore-hearth. A projecting bay in the front of a blast-furnace hearth, under the *tymp.* In *open-front* furnaces it is from the fore-hearth that cinder is tapped. See *Dam* and *Tymp.*

Forfeiture. The loss of possessory title to a mine or public lands by failure to comply with the laws prescribing the quantity of *assessment* work, or by actual abandonment.

Fore-poling. A method of securing drifts in progress through quicksand by driving ahead poles, lath, boards, slabs, etc., to prevent the inflow of the quicksand on the sides and top, the face being protected by *breast-boards.*

Forespar. See *Bloomary.*

Fore-winning, NEWC. Advanced workings.

Forge. 1. An open or semi-open *hearth* with a *tuyere.* 2. ENG. That part of an ironworks where *balls* are squeezed and hammered and then drawn out into *puddle-bars* by grooved rolls.

Forge-cinder. The slag from a forge or bloomary.

Formation. See *Geological formations.*

Fork. 1. CORN. The bottom of the *sump.* 2. DERB. A piece of wood supporting the side of an excavation in soft ground.

Forpale or *Forepale.* The driving of timbers or planks horizontally ahead at the working-face, to prevent the caving of the ground in subsequent driving.

Fossil ore. Fossiliferous red hematite.

Fother, NEWC. One-third of a chaldron.

Foundershaft. The first shaft sunk.

Fox-tail, S. WALES. The last cinder obtained in the *fining* process.

Frame, CORN. See *Tin-frame.*

Free. Native, uncombined with other substances, as free gold or silver.

Free fall. An arrangement by which, in deep boring, the *bit* is allowed to fall freely to the bottom at each drop or down-stroke.

Free-milling. Applied to ores which contain free gold or silver, and can be reduced by crushing and amalgamation, without roasting or other chemical treatment.

Freiberg amalgamation. See *Barrel amalgamation.*

Fritting. The formation of a slag by heat with but incipient fusion.

Frontal hammer or *Frontal helve,* ENG. A forge-hammer lifted by a cam, acting upon a "tongue" immediately in front of the hammer-head.

Frue vanner. A variety of continuously working *percussion-table.*

Fulguration. See *Blick.*

Furgen. A round rod used for sounding a bloomary fire.

Furnace. 1. A structure in which heat is produced by the combustion of fuel. 2. A structure in which, with the aid of heat so produced, the operations of roasting, reduction, fusion, steam-generation, desiccation, etc., are carried on, or, as in some mines, the *upcast* air-current is heated, to facilitate its ascent and thus aid ventilation.

Furnace cadmium or *cadmia.* The oxide of zinc which accumulates in the chimneys of furnaces smelting zinciferous ores.

Furtherance, NEWC. An extra price paid to *hewers* when they also *put* the coal.

Fuse. A tube or casing filled with combustible material, by means of which a blast is ignited and exploded.

Gad. 1. A steel wedge. 2. A small iron punch with a wooden handle used to break up ore.

Galemador, SP. A small Mexican furnace for roasting silver ores.

Gale, ENG. (Forest of Dean.) A grant of mining ground.

Galiage. Royalty.

Gallery. A level or drift.

Gallery-furnace. A retort-furnace used in the distillation of mercury.

Gallows-frame. A frame over a shaft, carrying the pulleys for the hoisting cables.

Galvanize. To coat with zinc.

Ganister. A mixture of ground quartz and fire-clay, used in lining Bessemer converters.

Gang. 1. A mine. 2. A set of miners.

Gangue. The mineral associated with the ore in a vein.

Gangway. 1. A main level, applied chiefly to coal mines. 2. NEWC. A wooden bridge.

Garland, S. STAFF. A trough or gutter round the inside of a shaft to catch the water running down the sides.

Gas-coal. See *Coal.*

Gas-furnace. A furnace employing gaseous fuel.

Gash. Applied to a vein wide above, narrow below, and terminating in depth within the formation it traverses.

Gas-producer. A furnace in which combustible gas is produced, to be used as fuel in another furnace.

Gas-well. A deep boring, from which natural gas is discharged.

Gate, Gate-way, or *Gate-road,* ENG. 1. A road or way underground for air, water, or general passage; a *gangway.* 2. The aperture in a founder's mould, through which the molten iron enters.

Gear, NEWC. 1. The working tools of a miner. 2. The mechanical arrangements connecting a motor with its work.

Geode. A cavity, studded around with crystals or mineral matter, or a rounded stone containing such a cavity.

Geological formations. Groups of rocks of similar character and age are called formations. The different stratified formations have been arranged by geologists according to their apparent age or order of position stratigraphically, and the fossils they contain. While there are minor points of difference in classification, and still more in nomenclature, the general scheme is now well settled. Three tables are given below, the first prepared in 1878, by Professor J. D. Dana, the second by Professor T. Sterry Hunt, both for the United States, and the third, referring to formations found in Pennsylvania only, by Professor J. P. Lesley. They are taken (Professor Hunt's, with later revision by the author), from *The Geologist's Travelling Handbook,* prepared by James Macfarlane, Ph.D. The numbers attached to the different formations in these tables will facilitate the identification of a given formation under different names. A catalogue of the formations is added to the tables, in which the predominant rocks of each are named. The eruptive rocks are not included in these tables, the determination of their age being a more difficult and doubtful matter, the discussion of which cannot be undertaken in this place. For lack of space, also, the enumeration and description of the different species of rocks and minerals must be omitted, the reader being referred for such information to works on lithology and mineralogy. (See next page.)

Geordie. The miners' term for Stephenson's safety-lamp.

German process. In copper smelting, the process of reduction in a *shaft-furnace,* after *roasting,* if necessary.

German silver. A white alloy of nickel, copper, and zinc.

German steel. See *Steel.*

Gerstenhöfer furnace. A *shaft-furnace* filled with terraces or shelves, through which crushed ore is caused to fall, for roasting.

Gig. See *Kibble.*

Gin. See *Whim.*

PROFESSOR J. D. DANA'S TABLE OF GEOLOGICAL FORMATIONS.

SYSTEMS OR AGES.		GROUPS OR PERIODS.	FORMATIONS OR EPOCHS.
Age of man.		20. Quaternary.	20. Quaternary.
Age of mammals.		19. Tertiary.	19 c. Pliocene. 19 b. Miocene. 19 a. Eocene.
Reptilian age.		18. Cretaceous.	18 c. Upper Cretaceous. 18 b. Middle Cretaceous. 18 a. Lower Cretaceous.
		17. Jurassic.	17. Jurassic.
		16. Triassic.	16. Triassic.
Carboniferous.		15. Permian.	15. Permian.
		14. Carboniferous.	14 c. Upper Coal Measures. 14 b. Lower Coal Measures. 14 a. Millstone Grit.
		13. Subcarboniferous.	13 b. Upper Subcarboniferous. 13 a. Lower Subcarboniferous.
Devonian or age of fishes.		12. Catskill.	12. Catskill.
		11. Chemung.	11 b. Chemung. 11 a. Portage.
		10. Hamilton.	10 c. Genesee. 10 b. Hamilton. 10 a. Marcellus.
		9. Corniferous.	9 c. Corniferous. 9 b. Schoharie. 9 a. Cauda Galli.
Silurian or age of invertebrates.	Upper Silurian.	8. Oriskany.	8. Oriskany.
		7. Lower Helderberg.	7. Lower Helderberg.
		6. Salina.	6. Salina.
		5. Niagara.	5 c. Niagara. 5 b. Clinton. 5 a. Medina.
	Lower Silurian.	4. Trenton.	4 c. Cincinnati. 4 b. Utica. 4 a. Trenton.
		3. Canadian.	3 c. Chazy. 3 b. Quebec. 3 a. Calciferous.
		2. Primordial or Cambrian.	2 b. Potsdam. 2 a. Acadian.
		1. Archæan.	1 b. Huronian. 1 a. Laurentian.

PROFESSOR T. STERRY HUNT'S TABLE OF GEOLOGICAL FORMATIONS.

AGES.	GROUPS.	AMERICAN FORMATIONS.
Cenozoic.	20. Quaternary.	20. Recent.
	19. Tertiary.	19 c. Pliocene. 19 b. Miocene. 19 a. Eocene.
Mesozoic.	18. Cretaceous. 17. Jurassic. 16. Triassic.	18. Cretaceous. 17. New Red Sandstone. 16. New Red Sandstone.
Paleozoic.	13–15. Carboniferous.	15. Permo-Carboniferous. 14. Coal Measures. 13 b. Mississippi (Carb. Limestone). 13 a. Waverley or Bonaventure.
	8–12. Erian or Devonian.	12. Catskill. 11. Chemung and Portage. 10. Hamilton (including Genesee and Marcellus). 9. Corniferous or Upper Helderb'g 8. Oriskany.
	5–7. Silurian.	7. Lower Helderberg. 6. Onondaga or Salina. 5 c. Niagara (including Guelph). 5 b. Clinton. 5 a. Medina. 5 a. Oneida.
	4. Upper Cambrian, Siluro-Cambrian, Ordovician, or Ordovian.	4 c. Loraine. 4 b. Utica. 4 a. Trenton.
	3. Middle Cambrian.	3 c. Chazy. 3 b. Levis (Tremadoc and Arenig). 3 a. Calciferous.
	2. Lower Cambrian.	2 e. Potsdam. 2 d. Sillery. 2 c. Acadian (Menevian). 2 b. Taconian. 2 a. Keweenian.
Eozoic.	1. Primary or Crystalline.	1 e. Montalban. 1 d. Norian or Labrador.* 1 c. Huronian. 1 b. Arvonian. 1 a. Laurentian.

* Professor Hunt says there are many reasons for believing that the Norian may be older than the Arvonian and Huronian.

PROFESSOR J. P. LESLEY'S PROVISIONAL NOMENCLATURE OF THE SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

	NAMES PROVISIONALLY ADOPTED.	Numbers used in first survey.
	20. Quaternary.	
	16. Triassic.	
	14 c. Upper Barren Measures.	XIII.
	14 c. Monongahela River Coal Series.	XIII.
	14 b. Lower Barren Measures.	XIII.
	14 b. Allegheny River Coal Series.	XIII.
	14 a. Pottsville Conglomerate.	XII.
Bernician.	13 b. Mauch Chunk Red Shale. (Umbral.)	XI.
	13 a. Pocono Gray Sandstone. (Vespertine.)	X.
Devonian.	12. Catskill Red Sandstone. (Ponent.)	IX.
	11 b. Chemung.	VIII.
	11 a. Portage.	VIII.
	10 c. Genesee.	VIII.
	10 b. Hamilton.	VIII.
	10 a. Marcellus.	VIII.
	9. Upper Helderberg.	VIII.
	8. Oriskany.	VII.
Silurian.	7. Lower Helderberg. (Lewistown Limestone.)	VI.
	5 b. Clinton.	V.
	5 a. Medina.	IV.
	5 a. Oneida.	IV.
Siluro-Cambrian.	4 c. Hudson River.	III.
	4 b. Utica.	III.
	4 a. Trenton.	II.
	3 a. Calciferous.	II.
	2 b. Potsdam.	I.
	1. Azoic.	

NOTES.—In the following notes Professor Hunt's classification is sufficiently followed to show the nature of the older groups which he distinguishes.

1a. *Laurentian.* Chiefly massive gneiss, reddish or grayish, sparingly micaceous, often hornblendic. Some crystalline limestone, magnetic iron, and other metallic ores.

1b. *Arronian.* Chiefly petrosilex, often becoming quartziferous prophyry, with some quartzites and hornblendic rocks; magnetic and specular iron ores.

1c. *Norian.* Chiefly a feldspathic rock (norite), which sometimes carries garnet, epidote, etc.; also, great beds of titaniferous iron ore.

1d. *Huronian.* Chloritic schists, greenstone (diorite or diabase), serpentine, steatite, dolomite, copper, chrome, nickel, and iron ores.

1e. *Montalban.* Fine-grained micaceous or hornblendic gneiss, chrysolite rock, serpentine, mica-schist, granite.

2a. *Keweenian.* The copper-bearing series of Lake Superior, made up of sandstones and conglomerates, with much interstratified eruptive rock.

2b. *Taconian.* Granular quartzites, argillites and nacreous or hydro-micaceous schists and great masses of crystalline limestone, marbles, magnetite, siderite, and pyrite changing to limonite.

2c and d. *Acadian* (and *Sillery*). Fossiliferous sandstone and shale.

2e. *Potsdam.* Sandstone, conglomerate.

3a. *Calciferous.* Sandy magnesian limestone, calcareous sandstone.

3b. *Quebec.* Sandstone, limestone conglomerate, black slate

3c. *Chazy.* Limestone, chert.

4a. *Trenton.* Limestone, buff and blue; dolomite carrying lead-ore deposits; brown-hematite beds.

4b. *Utica.* Dark carbonaceous slate; impure limestone.

4c. *Hudson River.* Slate, shale, clay, grit.

5a. *Medina.* Conglomerate; argillaceous sandstone.

5b. *Clinton.* Sandstone, shale, conglomerate, limestone, fossiliferous red hematite, or oolitic iron-ore bed.

5c. *Niagara.* Clay shale; limestone.

6. *Salina.* Red shale, gypseous shale, hydraulic lime, salt.

7. *Lower Helderberg.* Limestone, shaly or compact, and fossiliferous.

8. *Oriskany.* Sandstone.

9. *Corniferous or Upper Helderberg.* Principally limestone.

9a. *Cauda-galli.* Fine-grained calcareous and argillaceous, drab or brownish sandstone; peculiar fossils.

9b. *Schoharie Grit.* Fine-grained calcareous grit, similar to 9a, but with differing fossils.

9c. *Oncndaga*, and 9d. *Corniferous.* Gray, blue, black limestone. At the top of 9d occur the Marcellus iron ores (carbonate).

10a. *Marcellus.* Black or dark-brown bituminous and pyritiferous shales. In 10a and 9d occur the petroleum deposits of Canada.

10b. *Hamilton.* Slate, shale, sandstone, calcareous and argillaceous.

10b. *Tully.* Impure dark limestone.

10c. *Genesee.* Black clay slate.

11a. *Portage.* Green and black sandy and slaty shales, sandstone, flagstone.

11b. *Chemung.* Thin-bedded greenish sandstones and flagstones, with intervening shales, and rarely beds of impure limestone.

12. *Catskill.* Red, gray sandstone, grindstone grit, greenish shale, conglomerate.

13a. *Lower Subcarboniferous.* Sandstone, limestone, small local coal beds.

13b. *Upper Subcarboniferous.* Red shale, red and gray sandstone, blue limestone.

14a. *Millstone grit.* White or yellow sandstone, and conglomerate of quartz pebbles.

14b. and 14c. *Coal measures.* Fire-clay, shale, sandstone, conglomerate, limestone, bituminous coal, anthracite, iron ore, salt.

15. *Permian.* Limestone, sandstone, marl, shale.

16. *Triassic.* Red sandstone, red shale, conglomerate, lignite, trap dikes, copper ore, coal.

17. *Jurassic.* Marl, limestone, probably the gold-bearing slates of California.

18. *Cretaceous.* Earthy beds of sand, marl, clay, limestone, chalk, lignite.

19. *Tertiary.* Earthy sand, clay, marl, limestone, sandstone.

20. *Quaternary.* Sand, pebbles, boulders, clay, diluvium, alluvium; gravel and placer tin and gold deposits.

NOTE.—The primary and crystalline schistose rocks contain the larger number of mineral veins. The ancient magnesian limestones (probably Devonian) are characterized in many localities by deposits of argentiferous lead ore and of zinc ore.

Guillotine. A machine for breaking iron with a falling weight.

Gullet. An opening in the strata.

Gun-metal. An alloy of copper with tin or zinc, and sometimes a little iron. The common formula is nine parts copper to one tin. *Aich's metal* and some other gun-metals contain zinc and iron but no tin.

Gunnies or *Gunniss*, CORN. The vacant space left where the lode has been removed.

Hacienda, SP. Exchequer; treasury; public revenue; capital; funds; wealth; landed estate; establishment. In mining it is usually applied to the offices, principal buildings, and works for reducing the ores.

Hack. 1. See *Pick.* 2. A sharp blade on a long handle used for cutting billets in two.

Hade, DERB. See *Underlay.*

Hähner furnace. A continuously-working shaft furnace for roasting quicksilver ores. The fuel is charcoal, charged in alternate layers with the ore. The *Vall'Alta furnace* is a modification, having the iron tubes of the *Alberti.*

Hair-plate. See *Bloomary.*

Half-marrow, NEWC. Young boys, of whom two do the work of one *putter.*

Halvans, CORN. Ores much mixed with impurities.

Hammer-pick. See *Poll-pick.*

Hanging-coal. A portion of the coal-seam which, by the removal of another portion, has had its natural support removed, as in *holing.*

Hanging-guide. See *Guide.*

Hanging-side, or *Hanging-wall*, or *Hanger*, CORN. The wall or side over the vein.

Hazel. Freestone.

Hard head. A residual alloy, containing much iron and arsenic, produced in the refining of tin.

Hard lead. Lead containing certain impurities, principally antimony.

Hasenclever furnace. A roasting furnace, consisting of a long inclined channel (in its first form, a succession of inclined shelves in a shaft) down which the ore slides in a thin sheet, heated from below.

Head-gear. That part of deep-boring apparatus which remains at the surface.

Head-house. See *Gallows-frame.*

Heading. 1. The vein above a drift. See *Back.* 2. An interior

level or air-way driven in a mine. 3. In *long-wall* workings, a narrow passage driven upward from a gangway in starting a working in order to give a *loose end.*

Headings. In ore-dressing, the heavier portions collecting at the upper end of a buddle or sluice, as opposed to the *tailings*, which escape at the other end, and the *middlings*, which receive further treatment.

Head-piece. See *Cap.*

Headsman, NEWC. See *Putter.*

Head-stocks. See *Gallows-frame.*

Head-tree, NEWC. See *Cap.*

Headway, NEWC. See *Cross-heading.* The *headways* are the second set of excavations in *post-and-stall* work.

Heap, NEWC. The refuse at the pit's mouth.

Hearth. 1. The floor or *sole* of a reverberatory. 2. The *crucible* of a blast furnace.

Hearth-ends. Particles of unreduced lead ore expelled by the blast from a furnace.

Heat. One operation in a heating furnace, Bessemer *converter*, *puddling* furnace, or other furnace not operating continuously.

Heating-furnace. The furnace in which *blooms* or *piles* are heated before *hammering* or *rolling.*

Heave, CORN. A horizontal dislocation of a vein or stratum.

Helve. A *lift-hammer* for forging *blooms.*

Henderson process. The treatment of copper sulphide ores by roasting with salt, to form chlorides, which are then leached out and precipitated. Henderson originally proposed to volatilize the chlorides, and the leaching and precipitation are not original with him. *Longmaid* and many other metallurgists have proposed them in various modifications.

Hercules powder. See *Explosives.*

Hewer, NEWC. The man who *cuts* the coal.

Hitch, SCOT. and NEWC. 1. A minor dislocation of a vein or stratum not exceeding in extent the thickness of the vein or stratum. 2. A hole cut in the side-rock, when this is solid enough, to hold the *cap* of a set of timbers, permitting the *leg* to be dispensed with.

High explosive. An explosive or detonating compound developing more intense and instantaneous force than gunpowder. Most high explosives in general use contain nitroglycerin. See *Explosives.*

Hog-back. 1. A sharp anticlinal, decreasing in height at both ends until it runs out. 2. A ridge produced by highly tilted strata.

Hogger-pipe. The upper terminal pipe of the mining pump.

Hogger-pump. The topmost pump in a shaft.

Holing. 1. The working of a lower part of a bed of coal for bringing down the upper mass. 2. The final act of connecting two workings underground.

Hollow-fire, ENG. A kind of hearth with blast, used for reheating the *stamps* produced in the South Welsh process of fining, or the bars of *blister-steel* in the manufacture of *shear-steel.*

Hollway process. The removal of sulphur from iron and copper sulphides by fusion and pneumatic treatment, analogous to the manner in which carbon, etc., are removed in the Bessemer process.

Homogeneous metal. A variety of *ingot-metal* produced by the open-hearth process. See *Steel.*

Hopper. 1. A trap at the foot of a *shoot* for regulating the contents of a wagon. 2. A place of deposit for coal or ore.

Horn. See *Spoon.*

Horse, CORN. 1. A mass of *country-rock* inclosed in an ore-deposit. 2. See *Salamander.*

Horse-back, NEWC. A portion of the roof or floor which bulges or intrudes into the coal.

Horse-flesh ore, CORN. Bornite. See *Copper-ores.*

Horse-gin. Gearing for hoisting by horse-power.

Hot-bed. A platform in a rolling-mill on which rolled bars lie to cool.

Hot-blast. Air forced into a furnace after having been heated.

Hotching, NORTH ENG. See *Jigging.*

House of water, CORN. A cavity or space filled with water.

Howell furnace. A form of revolving roasting furnace.

H-piece. That part of a *plunger-lift* in which the valves or *clacks* are fixed.

Hudge. An iron bucket for hoisting ore or coal.

Hulk. See *Dzhu.*

Huel, CONN. See *Wheal.*

Hungry. A term applied to hard, barren vein-matter, such as white quartz (not discolored with iron oxide).

Hunt & Douglas process. The treatment of copper oxide (or roasted sulphide) ores by dissolving the oxides of copper in a hot solution of protochloride of iron and common salt. From the solution thus obtained, metallic iron precipitates metallic copper, at the same time regenerating the protochloride of iron for further use.

Hurdy-gurdy wheel. A water-wheel operated by the direct impact of a stream upon its radially-placed paddles.

Hushing. The discovery of veins by the accumulation and sudden discharge of water, which washes away the surface soil and lays bare the rock. See *Booming.*

Hutch. 1, SCOT. A low car, suited both to run in a level and to be hoisted on a cage. 2, CORN. A cistern or box for washing ore. See *Jig.*

Hydraulicking, PAC. Washing down a bank of earth or gravel by the use of pipes, conveying water under high pressure.

Idria furnace. See *Leopoldi furnace.*

Impregnation. An ore-deposit consisting of the country-rock impregnated with ore, usually without definite boundaries.

Inbye or *Inbyeside,* NEWC. Further into a mine, away from the shaft.

Incline. 1. A shaft not vertical; usually on the dip of a vein. See *Slope.* 2. A *plane,* not necessarily under ground.

Indicator. 1. An instrument for showing at any moment the position of the cage in the shaft. 2. An instrument for recording, by a diagram, upon a card the varying pressure of the steam in the cylinder of a steam-engine during the stroke.

Infiltration-theory. The theory that a vein was filled by the infiltration of mineral solutions.

Ingot. A cast bar or block of metal.

Injection-theory. The theory that a vein was filled first with molten mineral.

In place. Of rock, occupying, relative to surrounding masses, the position that it had when formed.

Inquartation. See *Quartation.*

Intake. The passage by which the ventilating current enters a mine. See *Downcast,* which is more appropriate for a shaft; *Intake* for an adit.

Inwalls. The interior walls or lining of a *shaft-furnace.*

Irestone. Hard clay slate; hornstone; hornblende.

Irestone or *Ironstone,* CORN. Greenstone.

Iron. The principal varieties of iron are *wrought-iron* and *cast-iron* (see *Pig-iron*). *Wrought-iron,* also called *bar-iron* and *weld-iron,* is the product of the forge or the puddling furnace, *cast-iron* of the blast furnace. The former approaches pure iron; the latter is an alloy of iron and carbon. Steel except some of the so-called "low"

or "mild" steels, which are more nearly wrought-iron (fused and cast) stands between them, having less carbon than cast-iron and more than wrought-iron. Some of the carbon in cast-iron is usually segregated during cooling in the form of graphite, and this determines the grade of the iron as *No.* 1 *foundry* (the most graphitic, coarsely crystalline, soft and black), *No.* 2 *foundry* (less open in grain), *gray forge* or *mill-iron* (still closer in grain, suitable for puddling), *mottled* (spotted with *white iron*), and *white* (hard, brittle, radially crystalline, containing its carbon mostly in alloy with the iron, and showing no visible graphite). These grades are also called simply No. 1, 2, 3, etc. So-called *silver-gray*, *glazy*, or *carbonized iron* is usually an iron rendered brittle by excess of silicon. *Ingot iron*, see *Steel*. *Anthracite*, *charcoal*, and *coke iron* are names given to pig-iron according to the fuel with which it is made.

Iron hat. See *Gossan.*

Iron-ores: Magnetic (*magnetite*, protoperoxide), *specular* (*hematite* proper, *red hematite*, anhydrous peroxide), *brown iron ore* (*hematite*, *brown hematite*, *limonite*, etc., hydrated peroxides), *spathic* (*siderite*, carbonate), clay-ironstone (*black band*, argillaceous *siderite*). See *Fossil ore.*

Iron-reduction process. See *Precipitation process.*

Ironstone. 1. Iron-ore. 2. See *Irestone.*

Jacket. A covering to prevent radiation of heat, as the jacket of a steam boiler; also, a casing around a furnace hearth in which water is allowed to stand or circulate to keep the walls cool.

Jackhead-pit. A small shaft sunk within a mine.

Jackhead-pump. A subordinate pump in the bottom of a shaft, worked by an attachment to the main pump-rod.

Jack-roll, NEWC. See *Windlass.*

Jadding or *Judding.* See *Holing.*

Jagging. A mode of carrying ore to the reduction-works in bags on horses, mules, etc.

Jars. A part of percussion-drilling apparatus for deep holes, which is placed between the *bit* and the *rods* or *cable*, and which by producing at each up-stroke a decided jar of the *bit* jerks it up, though it may be tightly wedged in the hole.

Jig-brow. See *Jinny-road.*

Jig-chain. S. STAFF. A chain hooked to the back of a *skip* and running round a post, to prevent its too rapid descent on an inclined plane.

Jigging, CORN. Separating ores according to specific gravity with a sieve agitated up and down in water. The apparatus is called a *jig* or *jigger*.

Jinny-road. A gravity plane underground.

Joachimsthal process. The extraction of silver from sulphuretted ores by converting into chloride, leaching with sodium hyposulphite, and precipitating the silver as sulphide with sodium sulphide.

Jowl, NEWC. A noise made for a signal by hammering at the faces of two levels expected to meet.

Judge, DERB. and NEWC. A measuring-stick to measure coal-work under ground.

Judd, NEWC. In *whole working*, a portion of the coal laid out and ready for extraction; in *pillar-working* (*i. e.*, the drawing or extraction of pillars), the yet unremoved portion of a pillar.

Jugglers. Timbers set obliquely against pillars of coal, to carry a plank partition, making a triangular air-passage or man-way.

Jump. 1, PAC. To take possession of a mining claim alleged to have been forfeited or abandoned. 2. A dislocation of a vein.

Jumper, CORN. and NEWC. A drill or boring tool, consisting of a bar, which is "jumped" up and down in the bore-hole.

Kann. See *Cand.*

Kast furnace. A small circular shaft furnace with three or four tuyeres, for lead smelting.

Keckle-meckle. The poorest kind of lead ore.

Keeve. 1. See *Cauf.* 2. A tub used in collecting grains of heavy ore or metal; a dolly tub.

Kernel-roasting. See *Roasting.*

Kevil, DERB. A veinstone, consisting of a mixture of carbonate of lime and other minerals.

Kibbal or *Kibble*, CORN. and WALES. An iron bucket for raising ore.

Kicker. Ground left in first cutting a vein, for support of its sides.

Kieve, CORN. A tub for *tozing* tin-ore.

Killas, CORN. Clay-slate.

Kiln. A furnace for the calcination of coarsely broken ore or stone; also, an oven for drying, charring, etc.

Kind's plug. A wooden plug attached to an iron rod, used in connection with sand for recovering *tubing* from *bore-holes.*

King-pot. The large central pot or crucible in a brass-melting furnace.

King's yellow. Sulphide of arsenic.

Kirving, NEWC. The cutting made at the bottom of the coal by the *hewer*.

Kish. The blast-furnacemen's name for the graphite-segregations seen in pig-iron and in the cinder of a furnace making a very gray iron.

Kit. A wooden vessel.

Kitchen. See *Laboratory* (2).

Knits or *Knots.* Small particles of ore.

Knobbling-fire. A *bloomary* for refining cast-iron.

Knockings. See *Riddle.*

Knox & Osborne furnace. A continuously working shaft-furnace for roasting quicksilver ores, having the fireplace built in the masonry at one side. The fuel is wood.

Knots. Small particles of ore.

Kröhnke process. The treatment of silver ores preparatory to amalgamation, by humid chloridization with copper dichloride.

Krupp washing process. The removal of silicon and phosphorus from molten pig iron by running it into a *Pernot furnace,* lined with iron oxides. Iron ore may also be added, and the bath is agitated by rotation for five to eight minutes only. See *Bell's dephosphorizing process.*

Labor, SP. Labor; work; a working. This term is applied in mining to the work which is actually going on, and to the spaces which have been dug out. It includes galleries, cavities, and shafts.

Laboratory. 1. A place fitted up for chemical analysis, etc. 2. The space between the fire and flue-bridges of a *reverberatory* furnace in which the work is performed; also called the *kitchen* and the *hearth.*

Ladle. A vessel into which molten metal is conveyed from the furnace or crucible, and from which it is poured into the moulds.

Lagging. Planks, slabs, or small timber placed over the caps or behind the posts of the timbering, not to carry the main weight, but to form a ceiling or a wall, preventing fragments of rock from falling through.

Lame-skirting, NEWC. Widening a passage by cutting coal from the side of it.

Lander, CORN. The man at the shaft-mouth who receives the *kibble*.

Landry-box, NEWC. A box at the top of a set of pumps into which the water is delivered.

Lath door-set. A weak lath-frame surrounding a main *door-frame*, the space between being for the insertion of *spills*.

Lath-frame or *crib*. A weak lath-frame, surrounding a main *crib*, the space between being for the insertion of *piles*.

Laths, CORN. The *boards* or *lagging* put behind the *durns*.

Launder, CORN. A wooden trough, gutter or sluice.

Lazadores, SP. Persons employed to collect workmen for a mine.

Lazyback, S. STAFF. The place at the surface where coal is stacked for sale.

Leaching. See *Lixiviation*.

Lead (pronounced like the verb *to lead*), PAC. See *Lode*.

Lead-fume. The fumes escaping from lead furnaces, and containing both volatilized and mechanically suspended metalliferous compounds.

Leader, CORN. A small vein leading to a larger one.

Lead-ores. *Galena* (*galenite*, sulphide); *antimonial lead-ore* (*bournonite*, sulphantimonide of lead and copper); *white lead-ore* (*cerussite*, carbonate); *green lead-ore* (*pyromorphite*, the phosphate, or *mimetite* or *mimetesite*, the arseno-chloride); *lead-vitriol* (*anglesite*, sulphate); *yellow lead-ore* (*wulfenite*, molybdate); *red lead-ore* (*crocoite*, chromate).

Lead-spar, CORN. Anglesite. See *Lead-ores*.

Leap, DERB. A fault. See *Jump*.

Leat, CORN. A watercourse.

Leath. Applied to the soft part of a vein.

Leavings, CORN. The ores left after the *crop* has been removed.

Ledge, PAC. See *Lode*.

Ledger-wall. See *Foot-wall*.

Leg. A prop of timber supporting the end of a *stull*, or the *cap* of a set of timber.

Leopoldi furnace. A furnace for roasting quicksilver ores, differing from the *Bustamente* in having a series of brick condensing chambers. Both are intermittent, *i. e.*, have to be charged and fired anew after each operation. The *California intermittent furnace* is a modification of the *Leopoldi*, having the fireplace on the side.

Level. A horizontal passage or drift into or in a mine. It is customary to work mines by levels at regular intervals in depth, num-

bered in their order below the adit or drainage level, if there be one.

Lewis. An iron instrument for raising heavy blocks of stone.

Ley, SP. Proportion of metal in the ore; fineness of bullion; also, an alloy or base metal.

Lid. A flat piece of wood placed between the end of a *prop* or *stempel* and the rock.

Lifters, CORN. The wooden beams used as *stems* for stamps in old-fashioned stamp-mills.

Lift-hammer. See *Tilt-hammer.*

Lifting-dog. A claw-hook for grasping a column of bore-rods while raising or lowering them.

Lignite. See *Coal.*

Limp. An instrument for striking the refuse from the sieve in washing ores.

Lining, NEWC. See *Dialling.*

Linnets, DERB. Oxidized lead-ores.

Liquation. See *Eliquation.*

Litharge. Protoxide of lead.

Lithofracteur. See *Explosives.*

Little Giant. A jointed iron nozzle used in hydraulic mining.

Lixiviation. The separation of a soluble from an insoluble material by means of washing with a solvent.

Location. 1. The act of fixing the boundaries of a mining claim, according to law. 2. The claim itself.

Loam. An impure potter's clay, containing mica or iron ochre.

Loch, DERB. and WALES. See *Vug.*

Lock-timber. An old plan of putting in *stull-pieces* in Cornwall and Devon. The pieces were called *lock-pieces.*

Lode, CORN. Strictly a fissure in the country-rock filled with mineral; usually applied to metalliferous lodes. In general miner's usage, a *lode, vein,* or *ledge* is a tabular deposit of valuable mineral between definite boundaries. Whether it be a fissure formation or not is not always known, and does not affect the legal title under the United States federal and local statutes and customs relative to lodes. But it must not be a placer, *i. e.,* it must consist of quartz or other rock *in place,* and bearing valuable mineral.

Lodge, WALES. See *Platt.*

Log, S. STAFF. A balance-weight near the end of the hoisting-rope of a shaft to prevent its running back over the pulley.

Longmaid process. See *Henderson process.*

Long tom, PAC. A kind of gold-washing cradle.

Long-wall. A method of coal mining by which the whole seam is taken out as the working faces progress, and the roof is allowed to fall behind the workers, except where passages must be kept open, or where the *gob* being packed in the space formerly occupied by the coal, prevents caving. According as the work of extraction begins at the boundary of the *winning*, and converges back to the shaft, or begins with the coal nearest the shaft and proceeds outward to the boundaries, it is called *long-wall retreating* or *long-wall advancing.*

Loob or *loobs*, CORN. The clayey or slimy portion washed out of tin-ore in *dressing.*

Loop. See *Loup.*

Loop-drag. An eye at the end of a rod through which tow is passed for cleaning bore-holes.

Loose-end. A gangway in *long-wall* working, driven so that one side is solid ground while the other opens upon old workings. See *Fast-end.*

Lorry. A hand-car used on mine tramways.

Lost level, CORN. "Level" is "lost" when a gallery has been driven with an unnecessarily great departure from the horizontal.

Loup. The pasty mass of iron produced in a *bloomary* or puddling furnace. See *Puddle-ball.*

Lowe, NEWC. A light. A "piece of lowe" is part of a candle.

Luckhart furnace. A continuously working shaft-furnace for roasting quicksilver ores, having the fireplace in the shaft at the bottom, protected by a cast-iron roof. The fuel is wood.

Lum. A chimney over an upcast pit.

Lump-coal, PENN. See *Coal.*

Lürmann front. An arrangement of water-cooled castings through which iron and cinder are tapped from the blast furnace, thus avoiding the use of a forehearth. See *Closed front.*

Lying-wall. See *Foot-wall.*

Machine-whim. A rotary steam-engine for winding.

Magistral, SP. A powder of roasted copper pyrites, used in the amalgamation of silver ores.

Main-rod, CORN. See *Pump-rod.*

Mainway. A *gangway* or principal passage.

Makings, NEWC. The small coals hewn out in *kirving.*

Malleable castings. Small iron castings made malleable by "annealing" or decarburizing by cementation in powdered hematite or other oxide of iron.

Mill-run, PAC. 1. The work of an amalgamating mill between two *clean-ups*. 2. A test of a given quantity of ore by actual treatment in a mill.

Mine. 1. In general, any excavation for minerals. More strictly, subterranean workings, as distinguished from *quarries*, *placer* and *hydraulic* mines, and surface or open works. The distinction between the French terms *mine* and *minière* results entirely from the law, and depends upon the depth of the working. The former is the more general term, and, ordinarily speaking, includes the latter, which signifies shallow or surface workings. 2. In a military sense, a mine is a subterranean gallery run under an enemy's works, to be subsequently exploded.

Mine-pig, ENG. See *Pig-iron*.

Miner, PENN. The workman who *cuts* the coal, as distinguished from the *laborer* who loads the wagons, etc.

Mineral. In miners' parlance, ore.

Mineral caoutchouc. Elastic bitumen.

Mineral charcoal. A pulverulent, lustreless substance, showing distinct vegetable structure, and containing a high percentage of carbon with little hydrogen and oxygen, occurring in thin layers in bituminous coal.

Mineralized. Charged or impregnated with metalliferous mineral.

Mineral oil or *Naphtha*. A limpid or yellowish liquid, lighter than water, and consisting of hydrocarbons. *Petroleum* is heavier than naphtha, and dark greenish in color when crude. Both exude from the rocks; but naphtha can be distilled from petroleum.

Mineral pitch. Asphaltum.

Mineral right. The ownership of the minerals under a given surface, with the right to enter thereon, mine, and remove them. It may be separated from the surface ownership, but, if not so separated by distinct conveyance, the latter includes it.

Mineral wool. See *Slag-wool*.

Mine-rent. The rent or royalty paid to the owner of a mineral right by the operator of the mine—usually dependent, above a fixed minimum, upon the quantity of product.

Mineria, SP. Mining. This term embraces the whole subject, including both mines and miners, and also the operations of working mines and of reducing their ores. It, however, is often used in a more restricted sense.

Minero, SP. Miner. This term is not limited to those who work mines, but includes their owners, and all who have the qualifications

prescribed in the ordinances, and are enrolled as members of the body or craft. Many of the laborers who work in mines are not, technically speaking, miners. This term is sometimes used in the old laws for *mine*.

Miners' inch, PAC. A local unit for the measurement of water supplied to hydraulic miners. It is the amount of water flowing under a certain head through one square inch of the total section of a certain opening, for a certain number of hours daily. All these conditions vary at different localities. At Smartsville, Cal., the discharge opening is a horizontal slit, 4 inches wide, in a 2-inch plank, with the standing head of water in the feed-box 9 inches above the middle of the slit. Each square inch of this opening will discharge 1.76 cubic feet per minute. A miners' inch in use in Eldorado County, Cal., discharges 1.39 cubic feet per minute. At North Bloomfield, Cal., and other places, the discharge is 50 inches long by 2 wide (giving 100 miners' inches) through a 3-inch plank, with the water 7 inches above the centre of the opening. Each inch is 1.50 to 1.57 cubic feet per minute in practice, or 59.05 to 61.6 per cent. of the theoretical discharge. These figures are taken from the paper of A. J. Bowie, Jr., on "Hydraulic Mining in California," *Trans. Am. Inst. M. E.*, vol. vi, p. 59.

Mineta, SP. A little mine; a chamber, or cavity.

Minium. Protosesquioxide of lead.

Mispickel, GERM. Arsenical pyrites.

Mistress, NEWC. A lantern used in coal-mines.

Mobby, S. STAFF. A leathern girdle, with small chain attached, used by the boys who draw *bowkes*.

Mock-lead, CORN. Zincblende.

Moil or *Moyle*, CORN. A drill pointed like a *gad*.

Monkey-drift. A small prospecting drift.

Monitor, PAC. A kind of nozzle used in *hydraulicking*.

Monnier process. The treatment of copper sulphide ores by roasting with sodium sulphate, and subsequent lixiviation and precipitation.

Monoclinal. Applied to any limited portion of the earth's crust throughout which the strata dip in the same direction.

Montefiore furnace. A peculiar furnace in which *zinc-dust* is compressed at a high temperature.

Moorstone, CORN. Loose masses of granite found on Cornish moors.

Oil-well. A dug or bored well, from which petroleum is obtained by pumping or by natural flow.

Old man. Ancient workings; *goaves.*

Old men. The persons who worked a mine at any former period of which no record remains.

Open cast, SCOT. See *Open cut.*

Open-crib timbering. Shaft timbering with *cribs* alone, placed at intervals.

Open cut. A surface-working, open to daylight.

Open-front. The arrangement of a blast furnace with a *fore-hearth.*

Open-hearth. See *Reverberatory furnace.*

Openings. The parts of coal mines between the pillars, or the pillars and ribs.

Opens. Large caverns.

Open-sand castings. Castings made in moulds simply excavated in sand, without *flasks.*

Open-work. A quarry or *open cut.*

Operator, PENN. The person, whether proprietor or lessee, actually operating a colliery.

Ore. 1. A natural mineral compound, of the elements of which one at least is a metal. The term is applied more loosely to all metalliferous rock, though it contain the metals in a free state, and occasionally to the compounds of non-metallic substances, as *sulphur ore.* 2. CORN. Copper-ore; tin-ore being spoken of in Cornwall as *tin.*

Ore-hearth. See *Scotch hearth.*

Ore-washer. A machine for washing clay and earths out of earthy brown-hematite ores.

Orpiment. Sesquisulphide of arsenic.

Outbye or *Outbyeside,* NEWC. Nearer to the shaft, and hence further from the *forewinning.*

Outcrop. The portion of a vein or stratum emerging at the surface, or appearing immediately under the soil and surface-*débris.*

Outlet. The passage by which the ventilating current goes out of a mine. See *Upcast.*

Output. The product of a mine.

Oval groove. A groove of U-section in a *roll.*

Overburden. 1. CORN. See *Burden* (1). 2. To charge in a furnace too much ore and flux in proportion to the amount of fuel. 3. The waste which overlies the good stone in a quarry.

Overman, ENG. The mining official next in rank below the *manager*, who is next below the *agent*.

Overpoled copper. Copper from which all the suboxide has been removed by *poling*.

Oxidation. A chemical union with oxygen.

Pack. A wall or pillar built of *gob* to support the roof.

Pair or *Pare*, CORN. Two or more miners working in common.

Pan. 1. See *Panning*. 2. A cylindrical vat of iron, stone, or wood, or these combined, in which ore is ground with *mullers* and amalgamated. See *Amalgamation*.

Pane. The striking-face of a hammer.

Panel. 1. A heap of dressed ore. 2. A system of coal-extraction in which the ground is laid off in separate districts or panels, pillars of extra size being left between.

Panning, AUST. and PAC. Washing earth or crushed rock in a pan, by agitation with water, to obtain the particles of greatest specific gravity which it contains (chiefly practiced for gold, also for quicksilver, diamonds, and other gems).

Parachute. 1. A kind of *safety-catch* for shaft cages. 2. In rod-boring, a *cage* with a leather cover to prevent a too rapid fall of the rods in case of accident.

Parcel, CORN. A heap of dressed ore ready for sale.

Parkes process. The desilverization of lead by treatment with zinc.

Parrot coal, SCOT. See *Coal*.

Parting. 1. A small joint in coal or rock, or a layer of rock in a coal seam. 2. The separation of two metals in an alloy, especially the separation of gold and silver by means of nitric or sulphuric acid.

Parting-sand. Fine dry sand, which is sifted over the partings in a *mould* to facilitate their separation when the *flask* is opened.

Pass, CORN. 1. An opening in a mine through which ore is shot from a higher to a lower level. See *Shoot*. 2. In rolling mills the passage of the bar between the *rolls*. When the bar passes "on the flat" it is called a *flatting-pass*; if "on the edge," an *edging-pass*.

Patent fuel, ENG. The fuel produced by the agglomeration of *coal-slack* into lumps.

Patera process. See *Joachimsthal process*.

Patio, SP. The yard where the ores are cleaned and assorted;

also, the amalgamation floor, or the Spanish process itself of amalgamating silver ores on an open floor.

Pattinson process. A process in which lead containing silver is passed through a series of melting-kettles, in each of which crystals of a poorer alloy are deposited, while the fluid bath, ladled from one kettle to the next, is proportionately richer in silver. In *mechanical pattinsonation* the operation is performed in a cylindrical vessel, in which the bath is stirred mechanically, and from which, as the richer alloy crystallizes, the poorer liquid is repeatedly drained out. *Steam pattinsonation* is a variety of the *Pattinson process*, in which steam is conducted through the lead bath to assist the refining.

Pavement. The *floor* of a mine.

Pay-streak. The zone in a vein which carries the profitable or *pay* ore.

Peach, CORN. Chlorite.

Pea-coal, PENN. See *Coal.*

Percussion-table. An inclined table, agitated by a series of shocks, and operating at the same time like a *buddle.* It may be made self-discharging and continuous by substituting for the table an endless rubber cloth, slowly moving against the current of water, as in the *Frue vanner.*

Pernot furnace or *Post-Pernot furnace.* A *reverberatory* puddling or smelting furnace, having a circular, inclined, revolving hearth.

Pershbecker furnace. A continuously working shaft-furnace for roasting quicksilver ores, having two fire-places at opposite sides. The fuel is wood.

Pertinencia, SP. The extent of a mining location in Mexico, to which a title is acquired by denunciation.

Peter or *peter out.* To fail gradually in size, quantity, or quality.

Pewter. An alloy of tin and lead. Other metals are often added, or the lead is replaced entirely with copper, zinc, antimony, etc.

Pick. A pick-axe with one or two points. The usual miners' pick has but one.

Picker or *Poker.* A hand chisel for *dzhuing*, held in one hand and struck with a hammer.

Pick-hammer. A hammer with a point, used in cobbing.

Pickling. Cleaning sheet-iron or wire by immersion in acid.

Pig. An ingot or cast bar of metal. See *Pig-iron.*

Pig-iron. Crude cast-iron from the blast furnace. When the furnace is tapped the molten iron flows down a *runner* moulded in

sand, from which it enters the *sows* or lateral runners, flowing from these again into the *pig-beds*, the separate parallel moulds of which form the *pigs*. In each bed the ingots lie against the *sow* like suckling pigs, whence the two names. See *Iron*. *Mine-pig* is pig-iron made from ores only; *cinder-pig*, from ores with admixture of some *forge* or *mill-cinder*.

Pike. See *Pick*.

Piking. See *Cobbing*.

Pile. 1. The *fagot* or bundle of flat pieces of iron prepared to be heated to welding-heat and then rolled. 2. To make up into *piles* or *fagots*. 3. *Piles* are long thick laths, etc., answering in shafts, in loose or "quick" ground, the same purpose as *spills* in levels, *piles* being driven vertically.

Pillar-and-stall. See *Post-and-stall*.

Pilz furnace. A circular or octagonal shaft-furnace, maintaining or increasing its diameter towards the top, and having several *tuyeres*; used in smelting lead-ores.

Pinch, CORN. To contract in width.

Pink ash, PENN. See *Coal*.

Pipe or *Pipe-vein*, DERB. An ore-body of elongated form.

Pipe-clay, U. S. A fine clay found in hydraulic mines.

Pipe-ore. Iron ore (limonite) in vertical pillars, sometimes of conical, sometimes of hour-glass form, imbedded in clay. Probably formed by the union of stalactites and stalagmites in caverns.

Piping. 1. PAC. See *Hydraulicking*. 2. The tubular depression caused by contraction during cooling, on the top of iron or steel ingots.

Pit. 1. A shaft. 2. A stack or *meiler* of wood, prepared for the manufacture of charcoal.

Pitch, CORN. 1. The limits of the *set* to tributers. 2. The inclination of a vein, or of the longer axis of an ore-body.

Pitch-bag, CORN. A bag covered with pitch, in which powder is inclosed for charging damp holes.

Pit-coal. See *Coal*.

Pit-eye, ENG. The bottom of the shaft of a coal-mine; also the junction of a shaft and a level.

Pit-eye pillar. A barrier of coal left around a shaft to protect it from caving.

Pit-frame. The framework carrying the pit-pulley.

Pitman. 1. CORN. A man employed to examine the lifts of pumps and the drainage. 2. NEWC. A working miner.

Pitwork, CORN. The pumps and other apparatus of the engine shaft.

Place. See *In place.*

Placer, SP. A deposit of valuable mineral, found in particles in *alluvium* or *diluvium*, or beds of streams, etc. Gold, tin ore, chromic iron, iron ore, and precious stones are found in placers. By the United States Revised Statutes all deposits not classed as veins of rock in place are considered placers.

Plane. An incline, with tracks, upon which materials are raised in cars by means of a stationary engine, or are lowered by gravity.

Plank-timbering. The lining of a shaft with rectangular plank frames.

Plank-tubbing. The lining of a shaft with planks, spiked on the inside of *curbs.*

Plat. The map of a survey in horizontal projection.

Plate-metal. See *metal.*

Plate-shale. A hard argillaceous bed.

Platinum-ores. Mixtures of native platinum in grains with various other metals and minerals.

Platt, CORN. An enlargement of a level near a shaft, where ore may await hoisting, wagons pass each other, etc.

Plattner process. See *Chlorination.*

Plomo, SP. Lead. *Plomo-plata*, lead-silver.

Plug. A hammer closely resembling the *bully.*

Plumb. 1. Vertical. 2. Soft.

Plumbago. Graphite.

Plunger. The piston of a force-pump.

Plush-copper. Chalcotrichite, a fibrous red copper ore.

Pocket. 1. A small body of ore. 2. A natural underground reservoir of water. 3. A receptacle, from which coal, ore, or waste is loaded into wagons or cars.

Podar. See *Mundic.*

Pointed boxes. Boxes in the form of inverted pyramids or wedges in which ores, after crushing and sizing, are separated in a current of water.

Pole-tools. The tools used in drilling with rods. See *Cable-tools.*

Poling. Stirring a metallic bath (of copper, tin or lead) with a pole of green wood, to cause ebullition and deoxidation in the refining process.

Polings. Poles used instead of planks for *lagging.*

Poll, CORN. The head or striking part of a miner's hammer.

-pick. A *pick* with a head for breaking away hard *partings* -seams or knocking down rock already seamed by *blasting.*

-oz (pronounced *Polrose*), CORN. The pit underneath a water-

sard furnace. A furnace in which the escaping combustion- passing through tubular flues, heat the incoming air continu- through the flue-walls.

pet-heads, CORN. A timber frame over a shaft to carry the g pulley.

. 1. A pillar of coal or ore. 2. An upright timber.

furnace. See *Pernot furnace.*

-and-stall. A mode of working coal, in which so much is pillar and so much is taken away, forming *rooms* and *thir-* The method is called also *bord-and-pillar, pillar-and-breast,*

tone. Compact steatite.

er's clay and *Pipe-clay.* Pure plastic clay, free from iron, and uently white after burning.

er-drill. See *Rock-drill.*

ious metals. See *Noble metals.*

ipitation process. The treatment of lead ores by direct fusion etallic iron or slags or ores rich in iron; performed generally *aft-furnace*, rarely in a *reverberatory.* Often combined with *sting and reduction process.*

n, CORN. Soft white clay.

ker. See *Needle.*

, CORN. 1. The best ore after cobbing. 2. See *Button.*

gap. The distance between two mining possessions in Der- .

luce. 1. The marketable ores or minerals produced by min- l *dressing.* 2. CORN. The amount of fine copper in one hun- arts of ore.

lucer. See *Gas-producer.*

. A timber set to carry a roof or other weight acting by ssion in the direction of the axis.

-crib timbering. Shaft-timbering with *cribs* kept at the distance apart by means of *props.*

pecting. Searching for new deposits; also, preliminary ex- ons to test the value of lodes or placers. The *prospect* is good

Proving-hole. A small *heading* driven to find and follow a coal-seam, lost by a dislocation.

Pryan. Ore in small pebbles mixed with clay.

Pudding-stone. A conglomerate in which the pebbles are rounded. See *Breccia.*

Puddle-bars. See *Forge.*

Puddle-steel. See *Steel.*

Puddle-train. A *train* of *rolls* for reducing squeezed *puddle-balls* to *puddle* or *muck-bars.*

Puddling. 1. The process of decarburizing cast iron by fusion on the hearth of a reverberatory furnace, lined (*fixed* or *fettled*) with ore or other material rich in oxide of iron. The bath is stirred with a *rabble* to expose it to the action of the lining and of an air current. The escape of carbonic oxide causes it to boil, whence the early name of this method of puddling, viz., *boiling. Dry puddling* is performed on a silicious hearth, and the conversion is effected rather by the flame than by the reaction of solid or fused materials. As the amount of carbon diminishes the mass becomes less fusible and begins to coagulate (*come to nature*), after which it is worked together into lumps (*puddle balls, loups*) and removed from the furnace to be hammered (*shingled*) or *squeezed* in the *squeezer*, which presses out the *cinder*, etc., and compacts the mass at welding heat, preparatory to rolling. Silicon and phosphorus are also largely removed by puddling, passing into the cinder. Mechanical *puddlers* (in which the bath is agitated by revolution, or by mechanical *rabbles*, to save hand-labor) are employed to a limited extent. 2. The term *puddling*, now applied in metallurgy exclusively to the above process, originally referred to the *puddling* of clay or clay and charcoal upon the masonry of a furnace hearth, to form a lining. Ditches, reservoirs, etc., are *puddled* with clay to make them water-tight.

Pug-tub. See *Settler.*

Pulley-frame. Gallows-frame.

Pulp, PAC. Pulverized ore and water; also applied to dry-crushed ore.

Pulp-assay, PAC. The assay of samples taken from the *pulp* after or during crushing.

Pump-bob. See *Bob.*

Pump-rod. The rod or system of rods (usually heavy beams) connecting the steam-engine at the surface, or at a higher level, with the pump-piston below. See *Balance-bob.*

Pump-station. See *Station.*

Punch or *Puncheon*. See *Leg*.
Punch-prop, NEWC. A short *prop*.
Put, NEWC. To convey coal from the working *breast* to the nway. This is usually done by young men (*putters*).
Putty-powder. Crude oxide of tin, used for giving opaque white- s to enamels, or for grinding glass.
Put-work. See *Tut-work*.
Pyrometer. An instrument for measuring high temperatures.

Quarry. An open or "day" working, usually for the extraction building-stone, slate, or limestone.
Quartation. The separation of gold from silver by dissolving out latter with nitric acid. It requires not less than $\frac{3}{4}$ silver in the y, whence the name, which is also applied to the alloying of gold h silver, if necessary, to prepare it for this method of *parting*.
Quartz. 1. Crystalline silica. 2. PAC. Any hard gold or silver , as distinguished from gravel or earth. Hence *quartz-mining*, listinguished from hydraulic, etc.
Quartzose. Containing quartz as a principal ingredient.
Quere, *queere* or *qweear*, CORN. A small cavity or fissure.
Quick. 1. Applied to a productive vein as distinguished from d or barren. 2. PAC. Quicksilver.
Quick ground. Ground in a loose incoherent state.
Quicksand. Sand which is (or becomes, upon the access of water) uick," *i. e.*, shifting, easily movable or semi-liquid.
Quicksilver-ores. See *Mercury-ores*.
Quintal. One hundred pounds avoirdupois.

Rabble. An iron bar bent to a right angle at the end. See *Pud- ng*.
Race. A small thread of spar or ore.
Rack, CORN. A stationary *buddle*.
Rafter-timbering. Timbering in which the pieces are arranged like rafters of a house.
Rag-burning, CORN. See *Tin-witts*.
Ragging. A rough *cobbing*.
Rail-train. A *train* of *rolls* for reducing iron *piles* or steel *ingots blooms* to rails.
Raise. See *Rise*.
Rake, DERB. A fissure vein crossing the strata.
Raking-prop. An inclined *prop*.

Ramble, NEWC. A shale bed on the top of a coal seam, which falls as the coal is removed.

Rancho, SP. An estate or property; a farm (PAC. *ranch*).

Random. The direction of a *rake-vein*.

Rapper. A lever or hammer at the top of a shaft or inclined plane, for signals from the bottom.

Raschette furnace. A shaft furnace used in lead, copper, and iron smelting, and having an oblong rectangular or oval horizontal section.

Reaction process. See *Roasting and reaction process*.

Realgar. Sulphide of arsenic.

Reamer. A tool for enlarging a bore-hole.

Record. To enter in the book of the proper officer (usually a district or county officer) the name, position, description, and date of a mining claim or location. See *District*.

Red-ash, PENN. See *Coal*.

Redevance, FR. A tax, duty, or rent. In mining law it means a tax or duty payable to the government or to the surface owner.

Red-lead. See *Minium*.

Red-short. Brittle at red heat. See *Cold-short*.

Reduce. 1. To deprive of oxygen. 2. In general, to treat metallurgically for the production of metal.

Reed, CORN. See *Spire*.

Reef, AUSTR. See *Lode*.

Refinery. See *Run-out fire*.

Refining. 1. The purification of crude metallic products. The refining of "base bullion" (silver-lead) produces nearly pure lead and silver. 2. The conversion of gray into white cast iron in a *run-out fire*.

Refractory. Resisting the action of heat and chemical reagents; a quality undesirable in ores, but desirable in furnace-linings, etc.

Regenerator. A chamber, filled with open-work of brick, to take up the heat of the gases of combustion from a furnace, and subsequently impart it to a current of air, the air and gas being conducted alternately through the chamber. See *Siemens furnace*.

Regule, FR. A copper *regulus* from which most of the impurities have been removed by liquation.

Regulus. 1. The metallic mass which sinks to the bottom of a furnace or crucible, separating itself by gravity from the supernatant *slag* or *matt*. 2. An intermediate product obtained in smelting ores, specially those of copper, lead, silver and nickel, and consisting

iefly of metallic sulphides. In this sense it is synonymous with *ıtt*, or the GERM. *Stein*. *Antimony regulus* is metallic antimony.

Rend-rock. See *Explosives*.

Renk, NEWC. The average distance coal is brough by the *putters*.

Rests. The arrangement at the top and bottom of a pit for supporting the shaft-cage while changing the tubs or cars.

Retorting. Removing the mercury from an amalgam by volatilizing it in an iron retort, conducting it away, and condensing it.

Reverberatory furnace. A furnace in which ores are submitted to e action of flame, without contact with the fuel. The flame enters m the side or end, passes upward over a low wall or *bridge*, strikes e roof (*arch*) of the furnace, and is *reverberated* downward upon e charge.

Reversing rolls. See *Three-high train*.

Rib. 1. In coal mining, the solid coal on the side of a gallery or ng-wall face; a pillar or barrier of coal left for support. 2. The id ore of a vein; an elongated pillar left to support the hanging-ll, in working out a vein.

Ribbed. Containing *bone*.

Ribbon-borer. A boring-tool consisting of a twisted flat steel ıde.

Rick, PENN. An open heap or pile in which coal is coked.

Riddle, CORN. and SCOT. A sieve. The large pieces of ore and ek picked out by hand are called *knockings*. The *riddlings* remain the riddle; the *fell* goes through.

Rider. See *Horse*.

Riffle. A groove or interstice, or a cleat or block so placed as to oduce the same effect, in the bottom of a sluice, to catch free gold.

Rim-rock. The bed-rock rising to form the boundary of a placer gravel deposit.

Ring, NEWC. A gutter cut around a shaft to catch and conduct ay the water.

Ringe. See *Cowl*.

Rise or *Riser*, CORN. A shaft or winze excavated upward.

Rise-heading. See *Heading, in long-wall*.

Rivelaine. A pick with one or two points, formed of flat iron, ed to undercut coal by scraping instead of striking.

Roasting. Calcination, usually with oxidation. *Good, dead*, or *et roasting* is complete roasting, *i. e.*, carried on until sulphurous l arsenious fumes cease to be given off. *Kernel-roasting* is a pro- s of treating poor sulphuretted copper ores, by roasting in lumps,

whereby copper (and nickel) are concentrated in the interior of the lumps.

Roasting and reaction process. The treatment of galena in a *reverberatory*, by first partially *roasting* at a low temperature, and then partially fusing the charge at a higher temperature, which causes a reaction between the lead-oxide formed by roasting and the remaining sulphide, producing sulphurous acid and metallic lead.

Roasting and reduction process. The treatment of lead ores by roasting to form lead-oxide, and subsequent reducing fusion in a shaft-furnace.

Rob. To extract pillars previously left for support; or, in general, to take out ore or coal from a mine with a view to immediate product, and not to subsequent working.

Rock-breaker. Usually applied to a class of machines, of which Blake's rock-breaker is the type, and in which the rock is crushed between two jaws, both movable, or one fixed and one movable. It is common to use a rock-breaker instead of hand-spalling to prepare ore for further crushing in the stamp-mill.

Rock-drill. A machine for boring in rock, either by percussion, effected by reciprocating motion, or abrasion, effected by rotary motion. Compressed air is the usual motive power, but steam also is used. The Burleigh, Haupt, Ingersoll, Wood, and other machines operate percussively; the *diamond drill* (which see) abrasively.

Rocker. A short trough in which auriferous sands are agitated by oscillation, in water, to collect their gold.

Rod-tools. See *Pole-tools.*

Rolley. A large truck carrying two *corves.*

Rolley-way. A *gangway.*

Rolling. See *Roll-train.*

Rolls. 1. Cylinders of iron or steel revolving towards each other, between which rock is made to pass, in order to crush it. 2. See *Roll-train.*

Roll-train. The set of plain or grooved rolls through which iron or steel *piles, ingots, blooms,* or *billets* are passed, to be rolled into various shapes.

Rondle or *Rondelle.* The crust or scale which forms upon the surface of molten metal in cooling.

Roof. The rock overlying a bed or flat vein.

Roofing. The wedging of a loaded wagon or horse against the top of an underground passage.

Room, SCOT. See *Breast* and *Post-and-stall.*

Rosette copper. Disks of copper (red from the presence of sub-xide) formed by cooling the surface of molten copper through prinkling with water.

Rossie furnace. An American variety of hearth for the treatment f galena, differing from the *Scotch hearth* in using wood as fuel, orking continuously, and having hollow walls, to heat the blast.

Roughing rolls. The *rolls* of a *train* which first receive the *pile*, *got*, *bloom*, or *billet*, and partially form it into the final shape.

Roughs, CORN. Coarse, poor sands, resulting from tin-dressing.

Round coal. See *Lump-coal.*

Rounder. See *Reamer.*

Row, CORN. Large, rough stones.

Royalty. The dues of the lessor or landlord of a mine, or of the wner of a patented invention.

Rozan process. An improvement of the *Pattinson process.*

Rubber. A gold-quartz amalgamator, in which the slime is rubbed gainst amalgamated copper surfaces.

Rullers, CORN. The workmen who wheel ore in wheelbarrows ndergrround.

Run, CORN. 1. The natural falling or closing together of under-round workings. 2. Certain accidents to the winding apparatus. *By the run.* A method of paying coal miners per linear yard of reast excavated, instead of *by the wagon* of clear coal produced. 4. long deep trough in which slimes settle. 5. See *Counter.*

Runner. The channel through which molten metal is conducted om the blast furnace or cupola to the *pig-bed*, *converter* or *moulds.* ee *Pig-iron.*

Run-out fire. A forge in which cast-iron is refined.

Run-steel. Malleable castings.

Rush, CORN. See *Spire.*

Rusty. Applied to coals discolored by water or exposure, as well to quartz, etc., discolored by iron oxide.

Rusty gold, PAC. Free gold, which does not easily amalgamate, he particles being coated, as is supposed, with oxide of iron.

Saddle. An anticlinal in a bed or flat vein.

Safety-cage. A cage with a *safety catch.*

Safety-car. See *Barney.*

Safety-catch. An automatic device for preventing the fall of a ge in a shaft or a car in an incline, if the supporting cable breaks.

Safety-lamp. A lamp, the flame of which is so protected that it

will not immediately ignite fire-damp. There are several varieties, invented by Davy, Stephenson, Clanny, and others.

Salamander. A mass of solidified material in a furnace hearth; called also a *sow* and *bear*.

Saline. A salt spring or well; salt works.

Sampson-post. An upright post which supports the walking-beam, communicating motion from the engine to a deep-boring apparatus.

Sand-pump. A cylinder with a valve at the bottom, lowered into a drill-hole from time to time, to take out the accumulated slime resulting from the action of the drill on the rock. Called, also, *Shell-pump* and *Sludger*.

Scaffold. An obstruction in a *blast furnace* above the *tuyeres* caused by an accumulation or shelf of pasty, unreduced materials, adhering to the lining.

Scal, CORN. A portion of earth or rock which separates and falls from the main body.

Scale. 1. The crust of metallic oxide formed by cooling of hot metals in air. *Hammer-scale* and *roll-scale* are the flaky oxides which fall from the *bloom, ingot,* or *bar* under hammering or rolling. 2. The incrustation caused in steam-boilers by the evaporation of water containing mineral salts. 3. A *scale of air* (NEWC.) is a small portion of air abstracted from the main current.

Scarcement. A projecting ledge of rock, left in a shaft as footing for a ladder, or to support pit-work, etc.

Scarfing. Splicing timbers, so cut that when joined the resulting piece is not thicker at the joint than elsewhere.

Schist. Crystalline rock, usually micaceous, having a slaty structure.

Schlicker, GERM. The skimmings from molten unrefined lead, containing chiefly copper, iron, and zinc, with a little antimony and arsenic.

Schorl. Black tourmaline.

Scoria or *Scoriæ.* See *Slag*.

Scorification. A process employed in assaying gold and silver ores, and performed in a shallow clay vessel (*scorifier*), in which ore, lead, and borax-glass are exposed to heat and oxidation in a *muffle*. The operation involves roasting, fusion, and *scorification* proper, or the formation of a slag, which is not, like the litharge produced in *cupellation*, absorbed by the vessel.

Scotch hearth. A low forge or furnace of cast-iron, with one *tuyere*,

n which rich galena is treated by a sort of accelerated *roasting and eaction process.*

Scouring cinder. A basic slag, which attacks the lining of a shaft-urnace.

Scovan lode, CORN. A lode having no *gossan* at or near the sur-ace.

Scraper. A tool for cleaning bore-holes.

Screen. A sieve of wire-cloth, grate-bars, or perforated sheet-iron sed to sort ore and coal according to size. Stamp-mortars have creens on one or both sides, to determine the fineness of the escaping ulp.

Screw-bell. A recovering tool in deep boring, ending below in a ollow screw-threaded cone.

Scrin or *Skrin,* DERB. A small subordinate vein.

Seam. 1. A stratum or bed of coal or other mineral. 2. CORN. A horse-load. 3. A *joint, cleft,* or *fissure.*

Seat, DERB. The floor of a mine.

Seed-bag. A bag filled with flaxseed and fastened around the ubing in an artesian well, so as to form, by the swelling of the laxseed when wet, a water-tight packing, preventing percolation lown the sides of the bore-hole from upper to lower strata. When he tubing is pulled up the upper fastening of the bag breaks, and t empties itself, thus presenting no resistance to the extraction of he tubing.

Segregate, PAC. To separate the undivided joint ownership of a nining claim into smaller individual "*segregated*" claims.

Segregation. A mineral deposit formed by concentration from the djacent rock.

Selvage, or *Selfedge.* A layer of clay or decomposed rock along vein-wall. See *Gouge.*

Semi-anthracite. See *Coal.*

Semi-bituminous coal. See *Coal.*

Separator. 1. A machine for separating, with the aid of water or ir, materials of different specific gravity. Strictly, a *separator* parts wo or more ingredients, both valuable, while a *concentrator* saves ut one and rejects the rest; but the terms are often used inter-hangeably. 2. Any machine for separating materials, as the *mag-etic separator,* for separating magnetite from its gangue.

Set or *Sett,* CORN. 1. A grant of mining ground, as the assign-nent of a certain part of a mine under contract or *tribute.* 2. A rame of timber for supporting excavations.

Settler. A tub or vat, in which *pulp* from the amalgamating *pan* or *battery-pulp* is allowed to settle, being stirred in water, to remove the lighter portions.

Shadd, CORN. Smooth, round stones on the surface, containing tin-ore, and indicating a vein.

Shaft. 1. A pit sunk from the surface. 2. The interior of a *shaft-furnace* above the boshes.

Shaft-furnace. A high furnace, charged at the top and tapped at the bottom.

Shaft-walls. 1. The sides of a shaft. 2. NEWC. Pillars of coal left near the bottom of a pit.

Shake. 1. A cavern, usually in limestone. 2. A crack in a block of stone.

Shaking-table. See *Percussion-table.*

Shambles. Shelves or benches, from one to the other of which successively ore is thrown in raising it to the level above, or to the surface.

Shearing. 1. The vertical side-cutting which, together with *holing* or horizontal undercutting, constitutes the attack upon a *face* of coal. 2. Cutting up steel for the crucible.

Shears, CORN. Two high timbers, standing over a shaft and united at the top to carry a pulley, for lifting or lowering timbers, pipes, etc., of greater length than the ordinary hoisting-gear can accommodate.

Sheathing. A close partition or covering of planks.

Sheave. The groove-wheel of a pulley.

Shelf, CORN. The solid rock or *bed-rock,* especially under alluvial tin-deposits.

Shell-pump. See *Sand-pump.*

Shelly. The condition of coal which has been so much faulted and twisted that it is not massive, but easily breaks into conchoidal pieces.

Shet, S. STAFF. The broken-down roof of a coal-mine.

Shift. 1. The time for a miner's work in one day. 2. The gang of men working for that period, as the *day-shift,* the *night-shift.*

Shift-boss. The foreman in charge of a *shift* of men.

Shingling. Hammering *blooms, billets,* etc.

Shiver. 1. Shale; a hard argillaceous bed. 2. See *Sheave.*

Shoad, CORN. Ore washed or detached from the vein naturally. See *Float-ore.*

Shoading or *Shoding*, CORN. The tracking of boulders towards vein or rock from which they have come.

Shoe. A piece of iron or steel, attached to the bottom of a *stamp muller*, for grinding ore. The shoe can be replaced when worn .

Shoot. 1. See *Chute.* 2. See *Blast.* A *shot* is a single operation blasting.

Shooting-needle. A sharp metal rod, to form a vent-hole through tamping to a blasting-charge.

Shore-nose shell. A cylindrical tool, cut obliquely at bottom, for ing through hard clay.

Show. 1. The pale-blue, lambent flame on the top of a common dle-flame, indicating the presence of fire-damp. 2. See *Blossom.*

Shute. See *Chute.*

Sicker. See *Zighyr.*

Siddle. The inclination of a seam of coal.

Side-basset. A transverse direction to the line of dip in strata.

Side-guide. See *Guard.*

Side-laning, S. STAFF. Widening a *gate-road* (abandoned for that rpose) so as to make it part of a new *side of work.*

Side of work, S. STAFF. The series of *breasts* and *pillars* connected h a *gate-road* in a colliery.

Siemens furnace. A reverberatory furnace, heated by gas, with aid of regenerators.

Sigger. See *Zighyr.*

Silesian zinc furnace. A furnace in which zinc is reduced and tilled from calcined ores in muffles.

Silicious. Consisting of or containing silex or quartz.

Sill. 1. A stratum. 2. A piece of wood laid across a drift to con- tute a frame with the posts and to carry the track of the tramway.

Silt. See *Alluvium.*

Silver ores. Silver-glance (*argentite*, sulphide); *horn-silver* (*cer- yyrite*, chloride); *dark-ruby silver* (*pyrargyrite*, sulphantimonide); *ht-ruby silver* (*proustite*, sulpharsenide); *brittle silver-glance* (*stepha- e*, antimonial sulphide of silver, and *polybasite*, arsenical and timonial sulphide of several metals); *white ore* (argentiferous ay copper, *tetrahedrite*, antimonial sulphide of iron, zinc, copper, d, and silver); *stetefeldtite* and *partzite* (antimoniates); also, argen- erous lead, copper, and zinc ores.

Sinker-bar. A heavy bar attached above the *jars* to *cable-drilling* ls.

Sinking-fire. A forge in which wrought-iron scrap or refined pig-iron is partially melted or welded together by means of a charcoal-fire and a blast.

Siphon-tap. See *Arends' tap.*

Sit or *Sits.* A settling or falling of the top of workings. See *Thrust* and *Creep.*

Sizing. Separating ores according to size of particles, preparatory to *dressing.*

Skep or *Skip,* CORN. An iron box working between guides, in which ore or rock is hoisted. It is distinguished from a *kibble,* which hangs free in the shaft.

Skew-plate. See *Bloomary.*

Skimmings or *Skimpings,* CORN. The poorest part skimmed off the *jigger.*

Skull. A crust of solidified steel lining a Bessemer ladle.

Slack. Small coal; coal dirt. See *Culm* (2).

Slag. The vitreous mass separated from the fused metals in smelting ores.

Slag-hearth. A hearth on the principle of the *Scotch-hearth* for the treatment of slags, etc., produced by lead-smelting in the *reverberatory furnace.* The English slag-hearth has one *tuyere;* the Castilian or Spanish, three.

Slag-lead. Lead obtained by a re-smelting of *gray slag.*

Slag-wool. A finely fibrous mass produced by blowing steam or air into molten slag.

Slant. A heading driven diagonally between the dip and the strike of a coal-seam; also called a *run.* See *Run* and *Counter.*

Slate. A sedimentary rock splitting into thin plates. The terms *slate, shale,* and *schist* are not sharply distinguished in common use, particularly among older writers. Strictly, according to recent authors, *slate* may be crystalline; *schist* is always so; shale is always (and *slate* most frequently) non-crystalline. There is also a notion of coarser or less complete lamination attached to the term *shale,* as of a rock splitting into thicker or less perfect plates than *slate.* Both may be argillaceous, arenaceous, calcareous, silicious, etc., according to their lithological character. The terms *slaty, shaly,* and *schistose* describe the respective structures.

Sleck, NEWC. Mud deposited by water in a mine.

Sleeper. See *Sill.*

Sleeping-table, CORN. A stationary *buddle.* For the strict distinction sometimes made between *buddle* and *table,* see *Buddle.*

lickeneides. Polished and sometimes striated surfaces on the s of a vein, or on interior joints of the vein-material or of rock-ses. They are the result of movement.

lide, CORN. 1. A vein of clay intersecting and dislocating a vein ically; or the vertical dislocation itself. 2. An upright rail l in a shaft with corresponding grooves for steadying the cages.

lide-joint. A connection acting in *rod-boring,* like the *jars* in *-boring.*

limes, CORN. The most finely crushed ores.

lme-table. See *Buddle.*

line. Natural transverse cleavage of rock.

lip. A vertical dislocation of the rocks.

lipes, S. STAFF. Sledge-runners, upon which a *skip* is dragged the working breast to the tramway.

lit. A communication between two levels.

litter. See *Pick.*

liver, ENG. A thin wooden strip, inserted into grooves in the cent edges of two boards of a *brattice,* to make it air-tight.

lope. See *Incline.*

ludge. See *Slimes.*

ludger. See *Sand-pump.*

luicing. Washing auriferous earth through long boxes (*sluices*).

lums, PAC. See *Slimes.*

lurry, N. WALES. See *Regulus* (2).

malt. A blue pigment or glass, consisting of silica, potash, and lt.

meddum, SCOT. The smaller particles which pass through the e of the *hutch.*

melting. Reducing ores by fusion in furnaces.

mift. A fuse or slow match.

mitham or *Smiddan,* DERB. Lead-ore dust.

mut. 1. S. STAFF. Bad, soft coal, containing much earthy ter. 2. See *Blossom.*

moff, CORN. A short candle-end, put under a fuse to light it.

more-hole. The hole in the lower part or *wind-bore* of a mining p, to admit the water.

oapstone. Compact talc or steatite; often applied incorrectly to unctuous clays or marls.

oftening. Of lead, the removal of antimony and other impurities.

older. A metal or alloy used to unite adjacent surfaces of less ble metals or alloys. *Soft solder* is a compound of tin and lead;

hard solder, of copper and zinc, or tin, copper, and zinc, or tin and antimony; *gold solder*, of gold, silver, and copper; *silver solder*, of silver and copper, or silver and brass; and so on.

Sole. 1. The bottom of a level. 2. The bottom of a reverberatory furnace.

Solid crib-timbering. Shaft-timbering with cribs laid solidly upon one another.

Sollar, CORN. A platform in a shaft, usually constituting a landing between two ladders.

Sough, DERB. See *Adit.*

Sow. 1. See *Salamander.* 2. See *Pig-iron.*

Spale, CORN. To fine for disobedience of orders.

Spall or *Spawl.* To break ore. *Ragging* and *cobbing* are respectively coarser and finer breaking than *spalling*, but the terms are often used interchangeably. Pieces of ore thus broken are called *spalls.*

Spar. A name given by miners to any earthy mineral having a distinct cleavable structure and some lustre; in Cornwall usually quartz.

Spears. See *Pump-rods.*

Speise or *Speiss*, GERM. Impure metallic arsenides (principally of iron), produced in copper and lead smelting. Cobalt and nickel are found concentrated in the speiss obtained from ores containing these metals

Spel or *Spell.* A change or turn.

Spence-furnace. A long *reverberatory*, for thorough roasting.

Spend. To break ground; to continue working.

Spiegeleisen. Manganiferous white cast-iron.

Spiking-curb, ENG. A *curb* to the inside of which *plank-tubing* is spiked.

Spilling, CORN. A process of driving or sinking through very loose ground.

Spills, CORN. Long thick laths or poles driven ahead horizontally around the door-frames, in running levels in loose ground—a kind of *lagging* put in ahead of the main timbering.

Spire. The tube carrying the train to the charge in a blast-hole. Also called *reed* or *rush*, because these, as well as spires of grass, are used for the purpose.

Spitting. The violent ejection of globules by a body of molten silver, in the act of becoming solidified by cooling.

Splint coal. See *Coal.*

plit. 1. To divide a ventilating current. 2. When a *parting* coal-seam becomes so thick that the two portions of the seam t be worked separately, each is called a *split.* See *Bench.*

ponge. Metal in a porous form, usually obtained by reduction hout fusion. See *Chenot process.*

poon. 1. An instrument made of an ox or buffalo horn, in which h or *pulp* may be delicately tested by washing to detect gold, lgam, etc. 2 (or *Spoon-end*). The edge of a coal-basin when coal-seam *spoons, i. e.,* rises to the surface, after growing thinner approaches its termination.

pout, S. STAFF. See *Air-head.*

prag. 1. A *prop.* 2. A short round piece of wood used to k the wheels of a car.

preader. A horizontal timber below the *cap* of a set, to stiffen *legs,* and to support the *brattice* when there are two air-courses he same gangway.

preaders. Pieces of timber stretched across a shaft as a tempo- support of the walls.

prue. A piece of metal attached to a casting, occupying the *gate* assage through which the metal was poured.

pud. A nail, resembling a horseshoe nail, with a hole in the l, driven into mine-timbering, or into a wooden plug inserted in rock, to mark a surveying-station.

spur. A branch leaving a vein, but not returning to it.

spurns, S. STAFF. Small connecting masses of coal, left for ty during the operation of cutting, between the *hanging coal* and main body.

Square sets. A kind of timbering used in large spaces.

Squat, CORN. 1. Tin-ore mixed with spar. 2. See *Bunch of*

Squeeze. The settling, without breaking, of the *roof* over a con- rable area of workings.

Squeezer. A machine for reducing the *puddle-ball* to a compact s, ready for the hammer or rolls.

Squib. A slow-match or safety-fuse, used with a *barrel.*

Squirting. Forcing lead by hydraulic pressure into the form of or pipes.

Stack. 1. A chimney. 2. See *Shaft-furnace.*

Stall, S. STAFF. See *Room, Breast,* and *Post-and-Stall.*

Stamping. Reducing to the desired fineness in a *stamp-mill.* The n is usually not so fine as that produced by grinding in *pans.*

Stamp-mill. An apparatus (also the building containing the apparatus) in which rock is crushed by descending pestles (*stamps*), operated by water or steam-power. Amalgamation is usually combined with the crushing when gold or silver is the metal sought, but copper and tin-ores, etc., are stamped to prepare them for *dressing*.

Stamps, S. WALES. The pieces into which the rough bars *shingled* from the finery ball are broken, to be *piled* for subsequent rolling into sheet-iron.

Stamp-work, LAKE SUP. Rock containing disseminated native copper.

Stanchion. See *Leg.*

Standage, ENG. A large *sump,* or more than one, acting as a reservoir.

Stannary. A tin-mine or tin-works.

Station. 1. See *Platt.* 2. Also, a similar enlargement of shaft or level to receive a balance-bob (*bob-station*), pump (*pump-station*), or tank (*tank-station*).

Steamboat-coal, PENN. See *Coal.*

Steam-coal. See *Coal.*

Steel. A compound or alloy of iron, principally with carbon, which may be cast, forged, hardened, and tempered. Ordinary steel contains from 0.5 to 1.5 per cent. of carbon. More carbon makes cast-iron; less carbon, wrought-iron. But this classification is not now strictly adequate or applicable, either to the scientific or to the commercial use of the term. The so-called *mild* or *low* or *structural* steels (low in carbon, and hence relatively soft and tough), as compared with *high* or *hard* or *tool* steels, do not always harden or temper. An international committee appointed by the American Institute of Mining Engineers has recommended the use of the following classification:

1. That all malleable compounds of iron with its ordinary ingredients, which are aggregated from pasty masses, or from piles, or from any forms of iron not in a fluid state, and which will not sensibly harden and temper, and which generally resemble what is called "wrought-iron," shall be called *weld-iron* (GERM., *Schweisseisen;* FR., *fer soudé*).

2. That such compounds, when they will from any cause harden and temper, and which resemble what is now called "puddled steel," shall be called *weld-steel* (GERM., *Schweissstahl;* FR., *acier soudé*).

3. That all compounds of iron with its ordinary ingredients, which have been cast from a fluid state into malleable masses, and which

ot sensibly harden by being quenched in water while at a red shall be called *ingot-iron* (GERM., *Flusseisen;* FR., *fer fondu*). That all such compounds, when they will from any cause so harhall be called *ingot-steel* (GERM., *Flussstahl;* FR., *acier fondu*). is proposed classification does not cover ordinary cast or pig iron. a classification of the malleable compounds only. The Institute ecommended its use in papers and discussions, except as to the *weld*, for which a substitute was desired, and meanwhile the nuance of the old term *wrought*, though in a somewhat wider icance, was suggested. The resolution of the Institute concludes lows: "It being understood that the *ingot-iron* and *ingot-steel* of lassification constitute, taken together, what is now commerknown as *cast-steel*, including the so-called low or soft cast." *Bessemer-steel* is made by decarburizing cast iron in a *con*. (See *Bessemer process.*) *Blister* or *cement-steel* is made by caring wrought iron bars by packing them in charcoal powder and ng without access of air. It is melted in crucibles to *cast-steel*, or nered (*tilted*) to *shear-steel* (for cutlery, etc.), or rolled to *spring*. *Puddled steel* is made by arresting the *puddling* process before ght iron has been produced, and thus retaining enough carbon bath to constitute steel. *Natural* steel is a similar product, ned from the refining of cast-iron. *Crucible cast-steel* is steel by the fusion in crucibles, either of *blister-steel*, or *puddled* or steel-scrap, or other ingredients and fluxes which will produce esired quality. *Cast-steel* in its widest sense, as now employed, rises all malleable compounds of iron produced by fusion, ining therefore the *Bessemer* and *open-hearth* metal. *Open-hearth*, also *Martin-Siemens steel*, is made in the reverberatory furnace st invariably a gas-furnace on the Siemens regenerative system, an intense temperature is required) by the reaction, in the bath, of cast-iron with wrought-iron, iron-oxide, or iron ore. certain stage of the process a *deoxidizing* or *recarburizing* agent *eleisen, ferromanganese*) is added. *Chrome-steel* is a crucible teel in which chromium is a constituent. *Tungsten* or *Wolf*teel is a steel containing tungsten. *Phosphorus-steel* is a steel ich the amount of phosphorus exceeds that of carbon. *Damas*el is a laminated mixture of steel and wrought iron. *India*r *Wootz* is manufactured in India direct from the ore.

nmer, NEWC. See *Tamping-bar*.

nming, NEWC. The tamping put above the charge in a bore-

Stempel or *Stemple.* 1. DERB. One of the cross-bars of wood placed in a mine-shaft to serve as steps. 2. A *stull-piece.* 3. A *cap,* both sides of which are *hitched* instead of being supported upon legs. See *Stull.*

Stenton, NEWC. A passage between two *winning headways.* A *stenton-wall* is the *pillar* of coal between them.

Step-grate. A grate made in steps or stairs, to promote completeness of the combustion of the coal burned upon it.

Step-vein. A vein alternately cutting through the strata of *country-rock,* and running parallel with them.

Stetefeldt furnace. A shaft-furnace for desulphurizing or chloridizing roasting, in which the pulverized charge falls freely down the shaft.

Stirrup. See *Temper-screw.*

Stockwork (GERM., *Stockwerk*). An ore-deposit of such a form that it is worked in floors or stories. It may be a solid mass of ore, or a rock-mass so interpenetrated by small veins of ore that the whole must be mined together. *Stockworks* are distinguished from *tabular* or *sheet*-deposits (veins, beds), which have a small thickness in comparison with their extension in the main plane of the deposit (that is, in *strike* and *dip*).

Stone-coal. See *Coal.*

Stone-head, ENG. The solid rock first encountered in sinking a shaft.

Stoop-and-Rooms, SCOT. See *Post-and-Stall.*

Stope, CORN. To excavate ore in a vein by driving horizontally upon it a series of workings, one immediately over the other, or *vice versa.* Each horizontal working is called a stope (probably a corruption of *step*), because when a number of them are in progress, each working face being a little in advance of the next above or below, the whole face under attack assumes the shape of a flight of stairs. When the first stope is begun at a lower corner of the body of ore to be removed, and, after it has advanced a convenient distance, the next is commenced above it, and so on, the process is called *over-hand* stoping. When the first stope begins at an upper corner, and the succeeding ones are below it, it is *under-hand* stoping. The term *stoping* is loosely applied to any subterranean extraction of ore except that which is incidentally performed in sinking shafts, driving levels, etc., for the purpose of opening the mine.

Stopping. 1. See *Stoping.* 2. A partition of boards, masonry,

rubbish, to stop the air-current in a mine, or force it to take a
ial desired direction.

Stove. The oven in which the blast of a furnace is heated.

Stove-coal, PENN. See *Coal.*

Stowbord, NEWC. A place into which rubbish is put.

Stowce. 1. A windlass. 2. DERB. *Stowces* are wooden land-
ks, placed to indicate possession of mining ground.

Stowing. A method of mining in which all the material of the
is removed and the waste is packed into the space left by the
king.

Straightening press. A power-press to straighten iron and steel
, such as rails, shafting, etc.

Strake, CORN. An inclined *launder* for separating or *tying* ground
in water.

Stratum. A bed or layer.

Streak. The powder of a mineral, or the mark which it makes
en rubbed upon a harder surface.

Stream-tin, CORN. Tin-ore in alluvial deposits, as pebbles.

Stream-work, CORN. Work on *stream-tin.*

Streamers, CORN. Searchers for *stream-tin.*

Striated. Marked with parallel grooves or *striæ.*

Strike. The direction of a horizontal line, drawn in the middle
ne of a vein or stratum not horizontal.

String, CORN. A small vein.

Stringing-deals, ENG. Thin planks, nailed to the inside of the
bs in a shaft, so as to suspend each curb from those above it.

Strip. To remove from a quarry, or other open working, the
rlying earth and disintegrated or barren surface rock.

Studdles, CORN. 1. Props supporting the middle of *stulls.* 2.
tance-pieces between successive frames of timbering.

Stull, CORN. A platform (*stull-covering*), laid on timbers (*stull-
ces*), braced across a working from side to side, to support work-
n or to carry ore or waste.

Stulm. See *Adit.* From the GERM. *Stollen.*

Stump, PENN. A small pillar of coal, left at the foot of a *breast*
protect the *gangway.*

Stup. A pulverized mixture of clay and coke or coal. Probably
n the GERM. *Gestübbe.*

Sturt. A *tribute*-bargain which turns out profitable for the miner.

Stythe, NEWC. *Choke-damp.*

Sublimation. The volatilization and condensation of a solid substance, without fusion.

Sublimation-theory. The theory that a vein was filled first with metallic vapors.

Sucker-rod. The *pump-rod* of an oil-well.

Sulphur. 1. Iron pyrites. 2. Carburetted or sulphuretted hydrogen.

Sulphurets, PAC. In miners' phrase, the undecomposed metallic ores, usually sulphides. Chiefly applied to auriferous pyrites.

Sump, CORN. (from GERM. *Sumpf.*). The space left below the lowest landing in a shaft to collect the mine-water. The lowest pump draws from it. 2. NEWC. That part of a *judd* of coal which is extracted first.

Sump-fuse. A waterproof fuse.

Swad, NEWC. A thin layer of stone or refuse coal at the bottom of the seam.

Swape. An implement for shaping the edge of a boring-bit.

Swalls, Swallows or *Swallow-holes.* Surface holes caused by the subsidence of rocks; or openings into which mine-water disappears.

Swamp. A depression in a nearly horizontal bed, in which water may collect.

Swedish process. See *German process.*

Sweeping table. A stationary *buddle.*

Sweeps. The dust of the workshops of jewellers, goldsmiths, silversmiths, and assayers and refiners of gold and silver.

Sweet-roasting. See *Roasting.*

Synclinal. The axis of a depression of the strata; also the depression itself. Opposed to *anticlinal,* which is the axis of an elevation.

Tackle, CORN. The *windlass,* rope, and *kibble.*

Tacklers, DERB. Small chains put around loaded *corves.*

Tail-house, Tail-mill. The buildings in which *tailings* are treated.

Tailing. See *Blossom.*

Tailings. The lighter and sandy portions of the ore on a buddle or in a sluice. The *headings* are accumulated or discharged at the upper end, the *middlings* in the middle, while the *tailings* escape at the foot. The term *tailings* is used in a general sense for the refuse of reduction-processes other than smelting.

Tail-race. The channel in which *tailings,* suspended in water, are conducted away.

Tamp. To fill (usually with clay-tamping) the bore-hole or other ning through which an explosive charge has been introduced for sting.

Tamping-bar, CORN.

Tank. A subterranean reservoir into which a pump delivers er for another pump to raise.

Tap-cinder. The cinder drawn from a *puddling*-furnace or mary.

Tap-hole. The opening through which the molten metal is ped or drawn from a furnace.

Teem, ENG. 1. To dump. 2. To pour steel from a melting-pot.

Temper. 1. To grind and mix plastic materials, such as clay, or ingredients of mortar. 2. To give the metals (especially steel) the red degree of hardness and elasticity by a process of heating and ing, suitably regulated. A metallic compound in which these lities can thus be produced is said *to temper*, or *to take temper.*

Tempering-bar. See *Furgen.*

Temper-screw. A screw-connection for lengthening the column of ing-rods as boring advances.

Tenant-helve, ENG. See *Frontal-hammer.*

Tepetate, SP. Waste rock and rubbish in a mine.

Terne-plate. A variety of tin-plate coated with an alloy of one-d tin, and two-thirds lead.

Test. See *Cupel.*

Test-ring. An oval iron frame for holding a test or movable elling-hearth.

Thermo-aqueous. Produced by, or related to, the action of heated ers.

Thill, NEWC. The floor of a coal mine.

Thirling. See *Thurling.*

Thomas and Gilchrist process. See *Basic lining process.*

Three-high train. A *roll-train* composed of three rolls, the bar ng entered on one side between the bottom and the middle roll, on the other side between the middle and the upper roll. The ses in both directions thus take place without reversing the move-nt of the rolls, as is done in so-called *reversing rolls.*

Throw. A dislocation or fault of a vein or stratum, which has n *thrown up* or *down* by the movement.

Throwing, S. STAFF. The operation of breaking out the *spurns*, s to leave the *hanging coal* unsupported, except by its own co-on.

Thrust. The breaking down or the slow descent of the roof of a *gangway.* Compare *Creep.*

Thurl, S. STAFF. To cut through from one working into another.

Thurlings. Passages cut from *room* to *room,* in *post-and-stall* working.

Thurst. The ruins of the fallen roof, after *pillars* and *stalls* have been removed.

Ticketings, CORN. Meetings for the sale of ores.

Tick-hole. See *Vug.*

Tierras, SP. Fine dirt impregnated with quicksilver ore, which must be made into *adobes* before roasting.

Tiger. See *Nipping-fork.*

Tile-copper. See *Bottoms* (2).

Tiller. See *Brace-head.*

Tilt-hammer. A hammer for shingling or forging iron, arranged as a lever of the first or third order, and "tilted" or "tripped" by means of a cam or cog-gearing, and allowed to fall upon the billet, bloom, or bar.

Tin-frame, CORN. A *sleeping-table* used in dressing tin-ore *slimes,* and discharged by turning it upon an axis till its surface is nearly vertical, and then dashing water over it, to remove the enriched deposit. A *machine-frame* or *self-acting frame* thus discharges itself automatically at intervals; a *hand-frame* is turned for the purpose by hand.

Tin-ores. Tinstone (*cassiterite,* oxide); *tin-pyrites* (*stannite,* sulphide of tin, copper, iron and zinc). The latter is not, so far as I am aware, now actually treated for tin. Ores containing it are smelted as copper-ores, and the tin is lost.

Tin-plate. Sheet-iron coated with tin.

Tin-witts, CORN. The product of the first dressing of tin-ores, containing, besides tinstone, other heavy minerals (wolfram and metallic sulphides). It must be roasted before it can be further concentrated. Its first or partial roasting is called *rag-burning.*

Tipe. To upset or "dump" a *skip.*

Toadstone. A kind of trap-rock.

Ton. For many things, such as coal and iron, the ton in use is the *long* ton of 20 hundredweight at 112 pounds avoirdupois. Allowances ("sandage," etc.), are made in weighing pig-iron and other crude metals, so that the "smelter's ton" is still greater. The Cornish mining ton is 21 hundredweight or 2352 pounds avoirdupois.

gold and silver mining, and throughout the Western States, the is the *short* ton of 2000 pounds.

Tonite. A nitrated gun-cotton, used in blasting.

Top-wall. See *Hanging-wall.*

Torta, Sp. A flat heap of silver ore (*slime* or *pulp*) prepared for *patio* process.

Tossing or *tozing,* Corn. 1. Washing ores by violent agitation in er, their subsidence being accelerated by *packing* or striking with ammer the *keeve* in which the operation is performed. *Chimming* similar process on a smaller scale. 2. Refining tin by allowing while molten, to fall several feet through the air.

Touchstone. A black, hard stone (basalt or jasper), on which the ness of an alloy of gold and silver can be tested by comparing its *ak* with that of a piece of alloy (*touch-needle*) of known fineness.

Tough-cake. Refined or commercial copper.

Toughening. Refining, as of copper or gold.

Tough-pitch. See *Tough-cake.*

Towt, Newc. A piece of old rope.

Train. See *Roll-train.*

Tram, Wales. 1. A four-wheeled truck to carry a *tub, corve,* or *h,* or to carry coal or ore on a railroad. 2. One of the rails of *amroad* or railroad.

Trap. In miners' parlance, any dark, igneous or apparently eous, or volcanic rock.

Trap-door. See *Weather-door.*

Trapiche, Sp. A rude grinding machine, composed of two stones, hich the upper is fastened to a long pole.

Trapper. Newc. A boy who opens and shuts the *trap-door.*

Tribute, Corn. A portion of ore given to the miner for his labor. *butors* are miners working under contract, to be paid by a *tribute* re or its equivalent price, the basis of the remuneration being amount of clean ore contained in the crude product.

Trip-hammer. See *Tilt-hammer.*

Trogue. A wooden trough, forming a drain.

Trolly. A small four or two-wheeled truck, without a body. two-wheeled trolly is used in a *rolling-mill* to wheel the *puddle-* to the *squeezer.*

Trombe or *Trompe,* Fr. An apparatus for producing an air-blast means of a falling stream of water, which mechanically carries down with it, to be subsequently separated and compressed in a rvoir or drum below.

Trommel. A revolving sieve for *sizing* ores.

Trouble, NEWC. A dislocation of the strata.

Trow. A wooden channel for air or water.

Trumpeting, S. STAFF. A small channel cut behind the brick-work of a shaft lined with masonry.

Trunk, CORN. A long narrow box or square tube, usually of wood.

Trunking, CORN. Separating slimes by means of a *trunk.*

Tubbing. A shaft-lining of casks or cylindrical caissons, of iron or wood. See *Plank-tubbing.*

Tubing. Lining a deep bore-hole by driving down iron tubes.

Tubs, NEWC. Boxes for lowering coals. See *Trolly.*

Tuff or *Tufa.* A soft sandstone or calcareous deposit.

Tug, DERB. The iron hook of a hoisting bucket, to which the *tacklers* are attached.

Tunnel. 1. A nearly horizontal underground passage, open at both ends to *day.* 2. PAC. See *Adit.*

Tunnel-head. The top of a *shaft-furnace.*

Turbary. A peat-bog.

Turn. A pit sunk in a *drift.*

Turn-bat. A wooden stick used in turning the tongs which hold a *bloom* under the hammer.

Turning-house. The first working on a vein where it has been intersected by a *cross-cut.*

Tut-work. See *Dead-work.* In general, work paid for by the amount of excavation, not (as in *tribute*) of product.

Tuyere, Tweer, Twyer or *Twere.* A pipe inserted in the wall of a furnace, through which the blast is forced into the furnace. Usually the tuyere enters through an embrasure in the masonry (*tuyere-arch*). A *nozzle* or interior pipe is frequently inserted at the inner end of the *tuyere.* By changing the *nozzle,* the size of the opening for the blast may be thus regulated without changing the *tuyere.* The latter is either an annular hollow casting of iron (*box-tuyere*) or bronze (*bronze tuyere*), or a coil of iron pipe. In either case, water is continually circulated through it, to protect it and the nozzle from the action of the melting materials in the furnace. *Spray-tuyeres* are open *box-tuyeres,* in which a spray of water, instead of a current, is employed. This is vaporized by the heat, and passes away as steam.

Tuyere-plate. See *Bloomary.*

Tying, CORN. See *Strake.*

Tymp. A hollow iron casting, cooled interiorly by a current of

er, and placed to protect the *tymp-arch*, or arch over the *dam*, in ast furnace having a *fore-hearth*. (See *Open front*.)

Under-hand. See *Stope*.

Underlayer, CORN. A vertical shaft sunk to cut a lode.

Underlie or *Underlay*, CORN. The departure of a vein or stratum the vertical, usually measured in horizontal feet per fathom of ned depth. Thus a *dip* of 60° is an *underlay* of three feet per om. The *underlay* expressed in feet per fathom is six times the ral cosine of the angle of the dip. See *Dip*.

Under-poled copper. Copper not *poled* enough to remove all sub-le.

Universal train. A *roll train* having adjustable horizontal and ical rolls, so as to produce sections of various sizes.

Unwater. To drain or pump water from a mine.

Upcast. 1. A lifting of a coal seam by a dike. 2. The opening ugh which the ventilating current passes out of a mine. See *ncast*.

Upraise. See *Rise*.

Ure's process. The treatment of quicksilver ores by heating in retorts with admixture of lime.

Vall' Alta furnace. See *Hähner furnace*.

Vamping. The *débris* of a stope, which forms a hard mass under feet of the miner.

Vanning, CORN. A method of washing ore on a shovel, analo-s to *panning*. Concentrating machines are sometimes called *ners*. See *Percussion-table*.

Vein. See *Lode*. The term *vein* is also sometimes applied to ll threads, or subordinate features of a larger deposit.

Vena, SP. A small vein.

Vend, NEWC. The total sales of coal from a colliery.

Verifier. A tool used in deep boring for detaching and bringing he surface portions of the wall of the bore-hole at any desired th.

Vermilion. Mercury sulphide.

Vestry, NEWC. Refuse.

Veta, SP. A vein. As compared with *vena*, *veta* is the main vein.

Viewer. A colliery manager.

Vigorite. See *Explosives*.

Vug, vugg, or *vugh.* A cavity in the rock, usually lined with a crystalline incrustation. See *Geode.*

Wad-hook. A tool with two spiral steel blades for removing fragments from the bottom of deep bore-holes.

Wagon. A four-wheeled vehicle used in coal mines, usually containing 75 to 100 cubic feet.

Wagon-breast. A *breast* into which wagons can be taken.

Wale, NEWC. To clean coal by picking out the refuse by hand. The boys who do this are called *Walers.*

Wall. 1. The side of a level or drift. 2. The *country-rock* bounding a vein laterally.

Wall-plates, CORN. The two side-pieces of a timber frame in a shaft, parallel to the strike of the lode when the shaft is sunk on the lode. The other two pieces are the *end-pieces.*

Washer. See *Ore-washer.*

Water-jacket. See *Jacket.*

Waste, NEWC. Old workings. The signification seems to include that of both *goaf* and *gob.*

Wastrel. A tract of waste land or any waste material.

Water-barrel or *Water-tank.* A barrel or box, with a self-acting valve at the bottom, used for hoisting water in lieu of a pump.

Water-level. 1. The level at which, by natural or artificial drainage, water is removed from a mine or mineral deposit. 2. A drift at the water-level.

Water-packer. A water-tight packing of leather between the pipe and the walls of a bore-hole.

Way-shaft. See *Blind-shaft.*

Weather-door. A door in a level to regulate the ventilating current.

Weathering. Changing under the effect of continued exposure to atmospheric agencies.

Wedging-curb or *Wedging-crib,* ENG. A *curb* used to make a water-tight packing between the *tubbing* in a shaft and the rock-walls, by means of split *deals,* moss, and wedges, driven in between the *curb* and the rock.

Weld. To join pieces of metal by pressure, at a temperature below that of complete fusion.

Weld-iron. Wrought-iron. See *Iron* and *Steel.*

Weld-steel. See *Steel.*

Well. The crucible of a furnace.

Welsh process. See *English process.*

Wetherill furnace. A furnace with perforated iron bottom, under ch a blast is introduced, and upon which zinc-ore (red oxide) is ced.

Wharl or *Wharr*, NEWC. A sledge for hauling corves in low s.

Wheal, CORN. A mine.

Whim or *Whimsey.* A machine for hoisting by means of a verti- drum, revolved by horse or steam power.

Whin or *Whinstone*, NEWC. Basaltic rock; any hard, unstrati- rock. In Scotland, greenstone.

Whip. The simplest horse-power hoisting machine, consisting of xed pulley and a hoisting rope passing over it, to which the ıal is directly attached.

White-ash, PENN. See *Coal.*

White-damp. A poisonous gas sometimes (more rarely than fire- p or choke-damp, etc.), encountered in coal mines. It has been posed to contain carbonic oxide, but this is doubtful.

White furnace. See *Howell furnace.*

White-lead. Carbonate of lead.

White tin, CORN. *Metallic tin.*

Whits or *Witts*, CORN. See *Tin-witts.*

Whitwell stove. A fire-brick hot-blast stove, on the regenerative em.

Whole-working, NEWC. Working where the ground is still whole, has not been penetrated as yet with breasts. Opposed to *pillar-* , or the extraction of pillars left to support previous work.

Wild lead. Zinc-blende.

Wicket. A *breast.* See *Breast*, and *Post-and-stall.*

Wimble. A shell-auger used for boring in soft ground.

Win. To extract ore or coal.

Windbore, NEWC. The pipe at the bottom of a set of pumps.

Winch or *Windlass.* A man-power hoisting machine, consisting horizontal drum with crank handles.

Winding. Hoisting with a rope and drum.

Winds. See *Winze.*

Winning. 1. A new opening. 2. The portion of a coal field laid for working.

Winning headways. NEWC. Headways driven to explore and out the coal seam.

Winze. An interior shaft, usually connecting two levels.

Wood-tin. Tinstone of light wood-color.

Wootz. See *Steel.*

Work. Ore not yet dressed.

Working. See *Labor.* The Spanish and the English term are synonymous in meaning and alike in application. A *working* may be a *shaft, quarry, level, open-cut,* or *stope,* etc.

Working-barrel, CORN. The cylinder in which a pump piston works.

Working home. Working toward the main shaft in extracting ore or coal, as in *longwall retreating.*

Working-out. Working away from the main shaft in extracting ore or coal, as in *longwall advancing.*

Work-lead. See *Base bullion.*

Yellow-ore. CORN. Chalcopyrite. See *Copper ores.*

Yokings. See *Stowces.*

Zawn, CORN. A cavern.

Ziervogel process. The extraction of silver from sulphuret ores or matte by roasting in such a way as to form sulphate of silver, leaching this out with hot water, and precipitating the silver by means of metallic copper.

Zighyr, zigger, or *sicker,* CORN. To percolate, trickle or ooze, as water through a crack. From the GERM., *sickern.*

Zinc-dust. Finely-divided zinc, zinc-oxide, and impurities, incidentally produced in the manufacture of *spelter.* It is sometimes used as an inferior paint (*zinc-gray*).

Zinc-gray. See *Zinc-dust.*

Zinc-ores. Red ore (*zincite,* oxide); *black-jack* (*zinc-blende, sphalerite,* sulphide); *zinc-spar* (*noble calamine, smithsonite,* carbonate, and *earthy calamine, hydrozincite,* hydrated carbonate); *silicious oxide* (*willemite,* anhydrous, and *calamine,* hydrated silicate).

Zinc-scum. The zinc-silver alloy skimmed from the surface of the bath in the process of desilverization of lead by zinc.

Zinc-white. Oxide of zinc.

Zones. In a shaft-furnace, the different portions (horizontal sections) are called *zones,* and characterized according to the reactions which take place in them, as the *zone of fusion* or *smelting-zone,* the *reduction-zone,* etc.

RAIL SPECIFICATIONS AND RAIL INSPECTION IN EUROPE.

BY C. P. SANDBERG, C.E., LONDON, ENGLAND.

INTRODUCTION.

OTWITHSTANDING the growing importance of this subject, no specially devoted to it has hitherto been published. Having to inspect during the last twenty years nearly a million tons on and steel rails for various countries, I have obtained ex- nce of what rail manufacturers can practically execute, as well what railway engineers practically require. Bearing these points in mind, I have from time to time published obser- ns with a view to unite both interests,—that of the producer hat of the consumer,—and to reduce the specifications and the s of sections to standards, or types, in order to facilitate the exe- n of the works and to improve the construction of permanent The Swedish government railways, as well as private com- s owning railways in Sweden, Norway, and Denmark, have g the time above mentioned consulted with me and intrusted e their rail inspection. I therefore owe to these countries much e opportunity which I have enjoyed of gaining experience and on. Next to Sweden, America is the country which has most lly favored me with its confidence in placing these matters in ands. Through circumstances not under my control there has little exportation to, and less work done by Europe for, America g the last six years; but the recent revival of the rail trade has the more gratifying to me, seeing that almost all the importers nerican rails are still specifying for the Sandberg rail sections nspection. It is therefore with feelings of gratitude that I now o lay before the American Institute of Mining Engineers, and I through that body, before the American railway world, the re- of some experience which I have gained in the execution of for their country, and which therefore belongs rightfully to

America. I should also mention in this introduction that I am greatly indebted to Canada for work intrusted to my care, and also to Russia, a country for which I have inspected very large quantities of rails, and from which I have received distinguished marks of honor. I propose in this paper to give a résumé of my experience as an independent rail inspector in the hope of benefiting both makers and consumers, and I intend to divide the subject into two parts—namely, Specification and Inspection, treating each part after my own method of proceeding, as being that with which I am naturally most familiar. Afterwards I shall compare my practice with that of other engineers in England and other parts of Europe.

Part I.

SPECIFICATION.*

Sandberg's Standard Sections of Iron Rails.—I have had principally to inspect the flange or flat-bottomed sections, which are used everywhere and are almost universally adopted except in England. After ten years' experience I was led to design my normal or standard sections from considering the enormous waste of time and money caused by the existence of different sections of the same weight, all intended to answer the same purpose. In 1870 I published a set of standard sections and circulated it in America and elsewhere, with the result of its being adopted largely in America, and in England for exportation. In the appendix to this paper† I have the pleasure to give the full description of these sections, which were principally made in iron but are now made in steel. I also give the specification which I used, and which seems to have given general satisfaction, inasmuch as none of these rails which have passed under my inspection, so far as I know, have broken, although they have of course had a fair amount of wear and tear. The peculiarities are chiefly equal width of base and height of rail and a good fishing angle, so as to obtain, if not a strong, at least a stiff joint, with ordinary fishing plates; the old pear-shaped forms, although easier to roll, cannot be joined with fish plates so that the bolts do not work loose. For this reason the fishing angle was reduced to a minimum compatible with convenience of rolling, viz., 22 degrees. With the minimum thickness of flange and web the rest of the weight is placed in the rail-head for wear. A medium

* Appendix I, Form of Specification.

† Appendix II, Standard Rail Sections.

on was obtained, which was just what makers could easily exe-
and what railway engineers required; and these are I think the
ns for the general adoption of my sections in the market. The
ailing opinion amongst European engineers of these sections is
they are too low and not stiff enough, and that there is an un-
ssary amount of width in base. They have no doubt reason for
opinion, as their sections require more stiffness than stability.
weight of their engines is not distributed over so many wheels as
ose of American railways; their curves are not so sharp; their
s are better maintained with good ballast, and therefore they
do with less width of base, but they want higher web for the
e weight of metal. European rail sections are therefore higher,
roportion to width of base, from $\frac{1}{2}''$ to $1''$. I am not now speak-
of the rails constructed for an iron permanent way,—one with
sleepers and cross-sleepers of iron or steel,—in which case the
ht is double the width of base. This is quite right, but for ordi-
wooden cross-sleepers uniformity of stiffness is what should be
d at. Yet, unhappily, with the ordinary form of fish we can only
in, even with the best fish angle and strongest bolts, one-quarter
ne-third of the stiffness of the joint compared with that of the
lle of the solid rail. It therefore matters little if we increase
tiffness of the solid rail by the increased height, as it is already
enough for any engine to run upon, compared with the weak-
of the joints; and the result is generally seen in flattened rail-
and sunken joints where they are laid on supported or on sus-
led sleepers.

ndberg's Standard Sections of Steel Rails.—With the use of
new material—steel—rail sections can be rolled easier with
ner flanges; moreover, they are not apt to laminate from im-
ct welding, like the iron. Notwithstanding the general adop-
of the iron sections already in use, this new metal caused a
and for improved sections of steel rails. Although confusion
ht be caused by the publication of a new set of standard sections,
t found myself bound to design such sections. I published
n in 1878, keeping them to what I had designed and executed
rge quantities for government and private railways. It would
oubtedly have been best theoretically to adhere to the main
ensions of rails and to the same forms of fish plates, and only to
ce the sections in flanges and web as much as the facility in
king the metal steel compared with iron would allow. Against
plan, however, is to be set the inconvenience, from a commer-

cial point of view, of interfering with the adopted weight. For instance, for 50 pounds and 56 pounds iron rails per yard, railmakers have their men's wages for rolling arranged to this fixed weight; further, railway engineers calculate the weight and cost of rails per mile to this weight; and I should have had little chance of getting the new sections adopted, even for the construction of new roads, if they had been reduced, for example, to 47 pounds per yard instead of 50, and to 53 instead of 56. Then for the construction of new roads engineers would say, "Let us have the greatest height (stiffness), width of base (stability), and bulk of rail-head (wearing capacity) which your rolling can produce for the given weight that is established commercially amongst the makers and is adopted by railway contractors." This principle was consequently followed, and new sections for steel were produced of the same weight as the old, viz., 50 and 60 pounds, with greater height than for the iron ones, and with 30 degrees fishing angle for steel, 22 degrees having been found rather too difficult in working. In consequence of having two different Sandberg sections for the same weight some confusion has naturally arisen, and in order to clear up the difficulty, and to explain matters fully, the designs of the two old 50 and 56 pounds rails published in 1870, as well as those of corresponding weight published in 1878, have been issued in the form of a separate drawing with explanations attached. This drawing has been largely circulated in America and Europe. The rails of the 1878 design have been supplied with angle fishing plates, and, although more costly, these offer greater width of base and stiffness of rail-joint, and they are adopted where localities and circumstances render them applicable. Particulars of these are also given in the drawing in Appendix II. Finally, a series of light sections from 20 to 50 pounds per yard, for secondary lines or railways of light traffic, were published some ten years ago, and have been adopted both in iron and in steel.

*Weight of Rail and Strength of Joint.**—The weight of rail ought to be considered together with the section and with the stiffness of rail, and from the railway engineer's point of view the rail-joint, as being the weakest part, is really the point of prime importance. When contractors, for instance, insert in their specification for building a road that the rail should weigh so many pounds per yard, they would naturally choose a lumpy section, impossible to fish properly,

* See article by the author, On the Strength of Rail-joints, in the Journal Iron and Steel Institute, No. II, for 1875.

ffering very little stiffness, so long as they could buy it cheaply. efore the stiffness of rail and rail-joint should be considered along the weight, and I have in my description of the Sandberg sec- (which may be found in Appendix II) tabulated the weight of vith the stiffness of both rail and rail-joint, and have given the mum safe load of each engine wheel. For example, the 50-pound vould carry 11 tons on 3 feet bearings without permanent set, the oint would carry 7.3 tons, and the maximum load of each l would be 5½ tons, and the maximum weight of the ordinary s engine to suit this rail would be 27½ tons. I fully admit this rule might not always be applicable, varying as it would local and other circumstances, but it is a simple and practical s of making sure that the rail is not overloaded, and more par- arly the rail-joint, for I have often found that the latter is the in ordinary practice. On the continent of Europe, for instance, -pound rail would generally carry 16 tons in the middle of the on 3 feet bearings, but the suspended joints might not carry than 4 tons, and the engine on its driving-wheel is often loaded or 6 tons; thus it would actually make the joint sink and take rmanent set every time it passed over the rail, and would result eaking the fish plates and flattening the rail-ends, making a bad anent way. Professor Rankine's rule is very much more waste- f material than the sections which I have designed, and as it was ed a long while ago it is quite time that rolling-stock en- ers should confer with permanent-way engineers in order to lay a rule for constructing rail sections, not considering weight uch as carrying capacity—a point which is, I believe, very neglected, or at least not considered in proportion to its im- nce.

ngth of Rails.—It follows that the longer the rail the more saving is in fastenings, and the better the road; but there is a limit be- which it is not practicable to go, not so much from the point of ufacture, as rails are now rolled in two or three lengths, but for of the easier handling and transport, both by land and by sea. long rails require separate wagons for overland transit; this ld be taken into consideration, and the normal length not fixed nd the practical limit. Now American engineers have gone to xtreme, and have chosen 30 feet as their normal length; in they are not stopping there, and it is naturally required that mported rails should be of the same length as those made at e. Not that English makers cannot roll them equally long as

Americans, but the cost of transport across the Atlantic increases with the length of the rail, as the vessels must be large in order to accommodate the greater lengths. Besides this, the longer the rail is the more likely it is to get crooked, especially on board ship; and on the road itself the plate-layers require some consideration, as they have quite enough to do to handle a rail of 30-foot length, especially if it is of good weight, say 56 pounds and upwards. I would, for my part, not go beyond 30 feet, and allow 10 per cent. of short lengths in even feet down to 20, and I would permit a variation in length of $\frac{1}{4}''$ above and below the regular measure. Considering that the rail cut off hot at the rolling contracts about 5″ more or less, according to its temperature when cut, $\frac{1}{4}''$ is not too much to allow, if we wish to avoid grinding it cold to the exact length. If the punch holes permit an opening of the joint of $\frac{1}{2}''$ there would be no reason whatever for not allowing $\frac{1}{4}''$ in the normal length, even when rails were renewed on the track one by one. On the continent of Europe engineers are very strict with the length, and do not allow more than a millimeter or two of variation, so that rail-makers have been obliged to make arrangements for grinding all rails, as they could not cut them near enough. This is becoming a great hindrance, especially where production is large and space limited; if we suppose an output of 2000 tons a week, which means 10,000 rails to be ground, a dozen grinding machines must be at work. The required space and the cost of working will naturally increase the cost of rail production, say several shillings per ton, which, of course, the railway companies would have to pay, without deriving any corresponding advantage from an improved track; for the grinding really does the rail more harm than good in point of durability. Such nicety in length as a millimeter is really not needed in practice, if the rail-joint be constructed so as to allow half an inch opening for expansion and contraction. What is of greater importance is to establish standard measures, so that all the rails for the same road, even if made at different works, would be cut to the same standard length, and this could easily be done by the inspectors using the same steel rod or Crown yard measure to correct the length to which the rails have to be cut before rolling commences. If this be neglected the 30-foot length made in one place may vary $\frac{1}{4}''$ and more from those made in another works, although makers may each have used their own standard measure.

Drilling, Punching, and Notching.—The bolt holes in rail-ends should be drilled in steel and punched in iron rails. The punching

otching of the steel rails was at first done in the same way as on rails, but as the material, when originally introduced, was hard it caused breakage through the bolt holes of a good many and I believe I am right in saying that nothing checked the uction of steel rails so much as the failure of that material gh treating it in the same rough mechanical way as that to iron was submitted. Iron, as a metal made from puddled ial, can stand a rough mechanical treatment which the ingot will not bear; and through neglecting to give attention to this ar feature of the new metal its introduction was greatly retarded, thstanding the excellent wearing results it gave as compared iron. I found this of such great importance that I carried out e number of comparative tests and experiments upon the loss ength which iron and steel rails suffer in different countries gh punching and notching, and I described the results in a hlet published in 1873.* It was shown by this investigation or punching there must be longer fish plates and a greater dis- between the end holes and rails, leaving solid material of say 2″ at least, which would mean longer centres and longer fish . To drill the bolt holes, of course, is the safest plan, particu- if the web is thick and the steel is hard. On the Continent eers keep to drilling exclusively, and makers are prepared to both round and oval holes without extra charge. Formerly vas a great objection amongst the English railmakers, but I am d to say that most of them are now willing to drill the holes, he extra charge made is little or nothing. Nevertheless, if it is pecified, they prefer the punching.

America the longer fish plates are preferred, and this may be t; but my theory is that it is not the length of the fish which s the stiffness of the joint, and it would be a waste of to extend it lengthways. If applied in the vertical direction ss is obtained in proportion to the square of the height. The of the holes punched in the fish plate must be guided by the of the bolt, which should have just so much play as not to round when screwed up. Although I have adopted a square- d bolt, and corresponding holes in the fish plate, I must admit he oval or elongated holes, with corresponding neck in the bolt, introduced are preferable, simply because they do not weaken h plate so much as the square hole. Anyhow the standard

* Appendix III, Effect of Notching.

bolt for each road should be kept so as to preserve a uniform plant, and to avoid the necessity of two sets of bolts and fish plates for the same railway. The fish plate should be punched hot and pressed.

The *notch* in the iron rail was formerly made in the middle of the rail, which was then thought desirable for preventing the road from travelling. As long as iron rails only were used, the plan worked with perfect success, for iron stands the rough treatment of notching in flanges in the middle of the rail without very great loss of strength, as is seen from the results of experiments above-mentioned (Appendix III). Quite different, however, was the result when steel was treated in a similar manner; it was then found that the notch placed in the middle took away almost the entire strength of the rails, so that they sometimes broke even in handling or in falling from a truck, and if they reached the road whole there were not many which did not break at an early period after being laid. This, as we have seen, retarded the introduction of steel rails, and it proceeded not from any fault in the material, but from ignorance of its proper treatment. The notch in the middle was consequently abandoned and moved to the ends; this materially improved matters, and nowhere now are any steel rails made notched in the middle.* There are two ways now adopted to prevent the road from creeping. Engineers' opinions differ very much as to the liability of a road to travel, for while some find that the rails, even in mountainous countries, as Norway, with gradients of one in a hundred, do not require any notching, others in a flat country, like Holland, have complained that the whole road was travelling in the direction of Rotterdam, and they weakened their rails by seven notches, one for every sleeper. However, we may admit that for single roads there is no actual danger of creeping, but for double roads it is necessary to prevent it, so that notching of both iron and steel rails must there be regarded as imperative. I would suggest its being done in two ways, depending upon whether the road is laid with supported or with suspended rail-joints; in the former case corner notches are quite suffi-

* Exceptions may, however, occur, and it so happened that in April last I was at the Hörde Works, in Germany, inspecting some steel rails for America which had a notch in the middle. At the same time Mr. Alexander L. Holley was there studying the Thomas-Gilchrist process. Rails were made by this process, and their strength compared by the falling test. They were found as strong as those of Bessemer steel, but the weakening effect of the notch was equally evident in both metals.

t, and have no weakening effect, but in the latter angle fish plates
t be used, these—and not the rails—to be notched or slotted
spike holes in the 2-joint sleepers. (See Appendix III.) Iron
, however, might be notched both at the corners and at 10″ on
side and 12″ on the other side; they would then suit for either
ng on supported or for suspended rail-joints. As to which of
e is preferable, a great difference of opinion exists amongst en-
ers. For my own part I prefer the supported. The size of the
hes in steel rails for a $\frac{1}{2}$″ spike may be taken as $\frac{3}{4}$″ and the depth
″, and the corner either left or right, as long as they always keep
he same, and at the reverse corner of both rail-ends; but the
h $\frac{1}{2}$″ long by $\frac{1}{2}$″ deep might be of slightly rounded corners, as
sharper it is the more it weakens the rail.

Marking.—The rail should be marked with the maker's name and
year of manufacture, and also with the word *steel* to distinguish
om iron. All these marks should be rolled on the web of the
in plain letters. The particulars are of great value and of com-
atively no cost. Besides these, the inspector's stamp on the end
ach rail after approval is of great importance. I have my well-
wn mark, a crown, hammered into each rail-end, and also the
als of my assistant, who passes the rails, so as to be able to refer
ach man's work and to make observations of results subsequently.
railway company or employer in each case receives a copy of the
ector's book, and I retain the original in my possession, along
all the documents relative to the execution and inspection of
order.

Mode of Manufacture.—For iron rails there was a great inclina-
at one time to introduce stipulations in the specifications that
ld, under all circumstances, secure a good rail; but, although
stipulations increased in severity year by year, the quality of the
rails gradually became worse. The result was that, where traffic
large and the endurance of rail of corresponding importance,
was adopted. At least there was no certainty of obtaining an
llent quality of iron rails through merely specifying the most
re terms for their manufacture. In former days they were made
superior quality of iron, which was capable of perfect welding,
naturally the results from the use of these were very satisfac-
. But these rails cost twice as much as steel rails do now, and
not to be expected that makers should now ruin themselves
upplying an extra quality of iron for an ordinary-priced article.
it was singular to watch the struggle between the producer and

the consumer to secure it. There were cases where an extra price was actually paid for the superior quality of iron desired, but with no improved result. It was thought that the use of cinder pig, made from puddled cinder containing a large proportion of sulphur and phosphorus, could not produce a good pig iron; nor could it afterwards give a puddled bar which would weld together in the rail pile. Railway engineers thought they would overcome this by stipulating for the use of only mine iron and no cinder pig. Unfortunately, however, there is as much difference in mine iron as between cinder and good pig, and two large districts in England, namely, Northampton and Cleveland, yield ore which contains as much phosphorus as, and even more than, the cinder pig. The pig iron consequently made from the pure mine, as it was called, produced equally bad iron, as unfit for welding in the rail pile as the other. The result was, that although an extra price was paid for mine iron rails they were no better than those obtained from the cinder pig. In fact, iron rails are not made nowadays of the same quality as they were thirty years ago, because there is no demand for the superior quality of iron rails since the introduction of steel. The latter will outlast by many times the iron rails in wear, and as for comparative merits, since the price is now not much more than that of the iron, or say but 10 per cent. higher, there is no question that steel in all instances has the preference. I would rather have steel rails of 20 per cent. less weight than iron. I should then gain 10 per cent. in the outlay, and I should surely get several times the amount of wear out of them. This, to my mind, shows a great mistake on the part of Americans in still importing iron rails, which is done at present in consequence of the difference in duty, this being almost double in the case of steel. During the construction of railways in Sweden iron rails were chiefly used, with the result of say fifteen to twenty years' life, but since steel became so cheap, and traffic increased, the renewals have all been made in steel rails. The mode of manufacture of both the iron and steel rails, as adopted in my specification, I believe is the simplest and most practical one, and is perfectly safe in the hands of any experienced inspector.

I could, however, fill a whole book with Continental specifications, many of which would much amuse both engineers and railmakers. I would do so if I thought them of any use, but my principle has always been to let the maker, to a great extent, choose his own method of manufacture, so long as he allows the inspector to see that the rails made are, first of all, safe and sound, then correct in every

rior part, to insure their being easily laid, thus giving a good and ght road likely to endure any reasonable amount of wear and that may be required. As for guarantee, I believe it to be use- where the railway is in constant communication with the maker, s to allow of the rails being watched from time to time, to see if are fairly treated; but where the manufacturer is distant from railway which consumes his article, I think it best for the rail- engineer to look after his interests by good inspection, and to e sure that he has got what his specification demands before the is paid for.

Part II.

THE INSPECTION OF RAILS.

is beyond doubt that the inspection of rails is a matter of great ortance. Whether it is necessary or not was at one time a de- d question, but it has long ago been decided in the affirmative. act, in Europe almost all rails are inspected, partly with a view conomical advantage to the railway, but principally with the in- ion of securing safety to the travelling public. In these times, n the material used and the mode of manufacture are so essen- y altered from what they were a few years ago, it behooves the way companies to do all they possibly can to insure public safety ell as to promote economy; and I believe I am right in saying these objects may be attained by the aid of competent supervi- of the manufacture, so that it may be seen that the requirements he specification are faithfully executed. On the other hand, an icient inspection is worse than none at all, because the fact of e being an inspection relieves makers from a responsibility which ht otherwise be felt. Then the question arises, What is a good in- tion? And the reply is: A competent, independent, and strict rvision of the daily make, testing the quality as well as passing the , and finally stamping and approving by certificate before the leaves the works, and is paid for. Unfortunately the requisite rience is not so easily obtained as railway presidents are apt to eve—a fact which is shown by their sometimes sending as in- tors such men as a draughtsman, or a captain of the army, who never have seen iron manufactured or rails rolled, and who has to n his business at the expense of the maker and his employers. As ecessary consequence the object in view is not obtained. An ector should be as much at home in the rail manufactory as the

maker himself, from the beginning to the end of the processes; and having the necessary moral power inspired by his knowledge, he should cause no unnecessary expense with his tests, but by adherence to the stipulations of the specification, secure a good rail of correct exterior and of sound inherent qualities. If the inspector has not been brought up in the iron manufacture with the necessary metallurgical and chemical knowledge, makers are only too prone to take advantage of his ignorance. This was more frequently the case in earlier days, when special delight was taken in deceiving the inspectors, particularly by the gaffers and workmen. I could give many instances from my twenty years' experience, amusing enough, illustrative of this. I am glad to say that now, at any rate, with my staff of inspectors, who are well known in all the European railmaking districts, such practices are seldom or never attempted. A maker naturally regards a stranger who comes to inspect one order only very differently from one whom he has seen more or less frequently, and whom he may soon have to meet again. It is certainly more easy to work under a constant system of inspection employed by a regular inspector, however strict it may be, than to submit to the changes demanded by different inspectors. Inasmuch as the mode of manufacture differs in each district, no general specification when laid out in great detail can be applicable in all of them. The differences in ore, in material, and in local circumstances, as well as in the machinery employed, make such detailed specifications impossible to be followed; and it is with this difficulty in view that I have limited my own specification to general terms in prescribing the mode of manufacture. If the specification were detailed, railway companies would not obtain any competition, but would have tenders from only a few works which would be able to fulfil the conditions of the specification sent out. Unfortunately we have not found a method to test every rail for quality, and until we do this inspections can only be partial. A suggestion was made some years ago to apply a registered manometer to the punching machine, and thus to measure the hardness of the steel; but the idea was stillborn, leaving us as before to the necessity of testing single bars. All that the inspector can do is to try to ascertain whether the bulk of the rails be quite equal to the samples tested.

However, as the quality of material may vary considerably, seeing that it depends on so many causes, it follows clearly that inspection is no *absolute* guarantee for obtaining safety and economy in each rail. All we may reasonably expect is that the general results

ood inspection should amply repay the small outlay incurred for and the railway company has a certain satisfaction in being able how to the shareholders as well as to the general public that all practicable means at its disposal for securing a good article e been employed. No one, however, can go so far as to hold inspector legally responsible for any accident through broken s, or failure of any other part of the work he has inspected, as he only certify that the specification has been carried out, and that nas done his best to secure a sound and reliable article. In order ut the inspector on an independent footing, not only with the kers, but also with the agents or all intermediaries, his work should paid by the railway authorities direct, and by no one else; and should also have to send his reports and certificates direct to m. The inspection, whether mechanical or chemical, should be ied out at the works, and should be final. Makers have a right to and this, and railway companies will have to obtain efficient inspec- by employing professional men, if they have none already in their ice. To approve of the rails provisionally at the works, and to at the tests and inspection on the arrival of the rails at their des- tion, and then if the two do not agree to reject the rails, is cer- ly unfair; but, nevertheless, I am sorry to say that this is done he stipulations made in some parts of Europe, notably in Ger- y and Russia. Rails tested in England for Russia during a l season do not give the same results when exposed to similar s in Russia under a low temperature; and loss to the maker or ractor follows, which is obviously unfair. This may have led he stipulation in one of the German rail specifications, which sed much amusement in England a year ago, namely, that the s should only be manufactured in the summer. Other German ifications stipulate that sample pieces from each blow in the con- er should be taken and forwarded to the railway authorities, who ld test them for tensile strength, and reject the rails made from blow if the sample should not come up to the required strength contraction of area. Meanwhile the rails would have been made, visionally approved of by the inspector, and sent away. The ker would be left in an awkward position with a large production, of 2000 tons per week, if he had to stock his ingots, waiting for results of the samples tested by the railway authorities. It seems that the specification for rails, since the introduction of the use of l, is becoming almost overdone—in America chemically, with stipulation of only one certain chemical composition in the rails;

and in Germany physically, in laying too much stress on contraction of area in fracturing samples to test tensile strength. For my part I do not hesitate to express my opinion that both systems are unpractical, as being not only costly but almost impossible to fulfil; nor even if carried out would they be in the end of any real use. It is true that the quality of iron rails deteriorated year after year, and it is no doubt through the fear that steel rails will also degenerate that these means have been resorted to. When the Bessemer process first was used for the manufacture of steel rails, only the very best and purest raw material could be used, such as contained neither sulphur nor phosphorus; but since then almost all sorts go into the pot and even phosphor-steel is now used for rails. But so far there is no proof of deterioration of the quality, although steel rails can now be got for one-third of the former price. It is natural, therefore, that a nervous feeling should seize the railway world to keep up the quality by specifying most stringent tests, both mechanical, physical, and chemical. I fear that after all they will be of little use. I have executed all three tests at great inconvenience, labor, and cost, and I have come to the conclusion that the simple falling test is all that is necessary, and it is in every respect sufficient. It is readily made at the works as soon as the rails are cold, and if it follows up the make of rails, it is a self-controlling agency which prevents the rejection of large quantities, as it tends to stop the manufacture of inferior steel. I shall, therefore, take the liberty of stating my mode of inspection as followed by my staff of inspectors,—a method which has given entire satisfaction both to producers and consumers. The inspection should closely follow the make, so that should anything objectionable arise the maker may be caused to remedy it at once, rather than to produce any large quantity of rails which would be rejected either because they do not come up to the test or for other faults.

Sandberg's System of Inspection.—My plan is as follows: The specification for either iron or steel rails is put into an inspection book, which my assistant has to keep as a record of the daily work, both as regards rejected and accepted rails.*

The specification is inserted in the inspection book, which the inspector strictly follows. Before the rolling commences the template is approved, the length to which the rails should be cut measured exactly with my standard steel rule, and gauges are checked and stamped, such as the female guage for sections,

* Appendix IV, Inspection Book.

ers for punching or drilling the bolt holes in the rail-ends for the notch holes in the flanges. As soon as the first bars e out they are weighed, and as the specification generally ulates that they should be rolled to a certain weight, ten bars weighed to see what the weight according to the section actually and then the rolls are screwed up or down to give the required ght, which will have to be observed, with the usual allowance of er cent. on single rails and 1 per cent. on the whole order. Crop- s are, as soon as they get cold, immediately tested with the falling ght, and if not strong enough the material is altered so as to ain the test properly. The control of the manufacture chiefly lies the approval of a correct section in rolling, particularly as he perfect fit of the fish plates. The inspection of the rails com- nces, as soon as there are any ready, straightened, punched, or led, first by measuring the length, then by determining whether y are straight, afterwards by examining the exterior correctness, clean surface, the freedom from cracks, or other imperfections; t by measuring the bolt holes and notches by the gauges; and lly by stamping (with the crown and assistant's initials) in the of the rail. Afterwards comes the reckoning by number of the erent lengths, and entering the accepted rails at the right hand e of the inspection book. All the rejected rails are entered on other side, in the columns arranged for them (for bad ends, being long, too short, crooked, twisted, or badly punched, and those cted for exterior faults, cracks, etc.). The rails so rejected, with exception of the radically bad ones, are taken out to be altered may then come again before the inspector. After each day's k an inspection report* is sent to the head office, and for every 0 tons inspected the inspection book is also sent; this is copied he head office and the copy is handed to the railway company or er employers, so as to acquaint them with the system and progress the inspection as well as with the results obtained in each indi- ual order. The original book, as well as all daily reports and documents belonging to the order, are kept together at the office. ekly and sometimes daily reports are issued from the head office he employers, to inform them of the progress of the manufacture inspection, and when the rails are shipped a certificate of inspec- † is issued against the copy of the bill of lading. No duplicate cer-

* **Appendix V**, Rail Inspection Report.

† **Appendix VI**, Inspector's Certificate.

tificates are ever issued. When the order is complete the results of the inspection as to rejection, etc., are entered in a book at the head office; and at the end of the year all the orders are tabulated and conclusions drawn from comparison of results. By the aid of this I am able to form my opinion for consultations, on the merit and value of each maker's production, and as this opinion is based on actual work inspected on the same system it ought to be thoroughly trustworthy. From time to time I personally visit the rail-making districts for the purpose of inspecting the work, especially when starting new orders and whenever any difficulty arises or any difference has to be settled. By the inspection carried out in this way security is given to the purchaser (so far as security can be obtained) that the specification has been followed. To the maker it is also an assistance rather than a burden or hindrance, for it aids him in the supervision and control of his daily manufacture. It avoids the loss in the rejection of large quantities, perhaps hundreds or even thousands of tons, as the system of inspection discovers the defect immediately. I think if the makers had the option of choosing between inspection during or after manufacture, they would surely prefer the former plan. I am pleased to say that I have but seldom been obliged to reject any large quantities, but I have often been obliged to ask the makers to alter the quality of the steel when that which was being used did not come up to the specified standard, and they have always been willing to make the change rather than run the risk of turning out rails of doubtful quality.

Tests for Iron and Steel Rails.—As for the tests applied, I have three in my specifications for iron and steel rails, namely, one for stiffness and dead-load; the second for quality and for wearing capacity; and the third, falling-tests for safety against breakage. Now the description of my standard section will show that I have laid down a rule to apply these tests according to the weight of the rail. For iron rails the weight of ball in hundredweights must be multiplied by the height of fall in feet to equal the weight of rail in pounds per yard. For instance, for an iron rail 56 pounds per yard, I prescribe a 7-hundredweight ball falling 8 feet on the rail supported on bearings 3 feet apart. I have always found this test sufficient, even for countries with cold climates, such as Scandinavia, Canada, and Russia. The effect of the blow should be a deflection of $\frac{3}{4}''$ to $1''$, and if that is not the result there must be some fundamental fault. The fall must then be increased so as to give the de-

on in one blow. For safety tests it is of great importance to tain that all rails are equal in strength, and as it would be unnec- y waste to try good rails my practice has generally been to every morning three crop-ends from the day and three from the t turn, and if these crop-ends stand the test (and they usually double the deflection of long rails) I may be quite sure that ails also will stand the test. Should, however, the crop-ends stand, the maker is immediately advised of the fact in order he may alter his iron; and the rails are then tested as per ification, taking out one from every hundred, and, in the event of reaking, dividing the bulk into 10 parts and testing again, so as ject 10 for every bar that breaks. This plan is the only practical but still it does not prevent the occasional acceptance of a few le rails, and this cannot be overcome until we find a suitable method esting each rail separately. The quality or wearing capacity of rails is tested by breaking crop-ends and rails under the press rder to ascertain that the welding is perfect; this is best deter- ed by breaking the flange first, in which case the slab would rate from the rail-head if it were not properly welded. Bad or l results in this respect are entered in the columns set apart for purpose in the inspection book, and an opinion may finally be ed whether the quality is one which can fairly be accepted. dead-load tests are then executed, but as the stiffness chiefly de- ls on the section and height of rail there is not so much varia- in the result as with the other tests. However, as a guide to t the rails ought to stand, I have tabulated the results in the ription of the standard rail sections. (Appendix, No. II.) As iron (except for exportation to America) are considered in Europe thing of the past, this is of less practical interest than the sub- of steel rails. But I am sorry to say that we are yet far from g unanimous as to the best system of inspecting steel rails, I may give here the final paragraph from a report by a govern- t engineer on this subject, where he says: "A diversity pinion amongst men so experienced as yourself and the eminent orities above named, leads to the conclusion that engineers like ors often honestly differ upon the best means of obtaining simi- esults." I will, however, state the manner adopted by myself he inspection of steel rails, which, as far as my experience goes, hitherto given equally good results with those followed in in- ting iron rails. I have carried out the inspection of steel rails cipally in the same way as that of iron, but with very much

more severe tests. The question has arisen why steel rails should be expected to sustain more stringent tests than iron, and the question has been argued from both sides. It seems that in order to make up for the variable hardness of the steel rails a more severe test is needed to secure a soft metal for rails. Where would engineers be if steel rails were tested with no heavier falling test than that used for iron rails? The makers would produce a much harder rail, because the hard metal rolls more easily, is more easily blown and with less waste, but then the breakages would surely be much more numerous than they now are. The superiority in the wearing qualities of steel over iron rails is no doubt due principally to the solidity of a material not apt to laminate, like the iron rail made from a pile. But it is doubted which is the more durable, the hard or the soft rail. For my part I agree with Professor Tunner that a rail of medium hardness, possessing the greatest absolute strength, is the best.* Be this as it may, the safety of the rail is the main point, and the simplest way of securing this is by the test of a heavy falling weight. I have, for instance, adopted four to five times the blow for steel as for iron; a ton weight falling 20 feet for a heavy rail, say 60 pounds and above; and 15 feet for a 56-pound rail. A deflection of 3 or 4 inches should result from this, according to the hardness of the steel. Now I have not thought it necessary nor expedient to stipulate as to the mode of manufacture, either in Bessemer, Siemens, or even the Thomas steel, so long as the result obtained by the testing shows strength as above, solid fracture, and exterior correctness. Nothing more need be expected. But a practical test of very great value, which my inspectors have to superintend each day during the make, is that in which the maker himself, for his own satisfaction, tests every blow mechanically by having a sample ingot hammered out to a bar 1″ by ½″, which should when cold stand bending at least to right angles. One end of this bar should be nicked and dipped into water and broken to expose the fracture, and the corresponding blow of the Bessemer has in each case to be approved by the foreman of the works before the ingots are taken to the rail mill. Should the steel break, the cast must not be used, and the blowing metal must be changed immediately so as to produce a superior material. In this case a chemical analysis—for carbon, silicon, and phosphorus—is made in order to discover the cause of the metal being too hard or too brittle. This self-control of the maker is of greater value than any testing

* See Appendix IX.

h could be made of the rails afterwards; and I am pleased to that the plan is instituted at almost every steel works in ope. Formerly more stress was laid upon the chemical test for on, and every cast was analyzed for carbon by the coloration test Eggertz. This is now, however, less insisted on, since it is vn that other hardening substances besides carbon may equally the strength. Neglect to use the mechanical test on every cast result in the production of large quantities of ingots which, rolled out into rails, will not stand the tests inflicted, and I quite lately had the very unpleasant duty of rejecting three or hundred tons of rail which had been produced from a too sili- pig iron, the steel containing $\frac{3}{4}$ per cent. of silicon, and break- at much lower tests than ought to have been the case. The uction of good steel of uniform quality, by the basic process of nas and Gilchrist, depends entirely upon the mechanical tests.

esults of Inspection.—I may mention that the result of my in- ion of steel rails during the past ten years on the system e described, taking the average of more than twelve works in and, is that the preliminary rejection at the first inspection been 13 per cent. More than half the rails were rejected for being straight, and the remainder for faults detailed in the in- ion book. Of course after being re-straightened, re-cut, etc., nese rails would probably be accepted, so that the final amount ted would only be from 1 per cent. to 2 per cent. This of se has nothing to do with that portion which the makers selves reject before the rails are put upon the inspection hes; this may be taken as about equal to the other, so that total amount ordinarily rejected in the manufacture may be nated to be about 3 per cent. I do not mention the names ny makers, but I may say that I have had to inspect work lmost every rail mill in England, and, having kept my s carefully, I take the average of the work of English rail- ers in general. Regarding the straightening of steel rails I ve it to be a very important question. The present method is ame as that used for iron rails, and this is the cause of nearly ne breakages of steel rails, when they get on the road. For the gth is liable to be impaired by the rough treatment in bending ail under the press with the hammer gags cut on the flanges; in steel will not stand so much rough usage in this way as iron. efore straightening hot must be introduced sooner or later. Last nn I drew public attention to this in an article which appeared

in *Engineering* of 10th October, 1879,* but I have to add that the method which I was then hopeful would answer has not proved quite as efficient as I expected. I allude to the curving or bending machine. It certainly does take out all twists, but it does not lessen the straightener's labor as much as I anticipated.

Having thus described my method of inspection, both of iron and of steel rails, I think you will no doubt have seen that there is no mystery or secrecy about it, or in fact anything extraordinary in the whole method. There is simply a good supervision of the make from beginning to end, and constant attendance during the manufacture of honest practical experienced men. All observations are recorded, and conclusions drawn from them.

Even if a railway company kept a competent man who would do the same, it follows that his practice would be limited; and, therefore, an engineer making a specialty of the business of inspection, and doing nothing else but inspect for various employers and in different districts, must naturally gain ten times more experience than any one would be able to obtain from practice supplied by a single company, which, unless it were a very large one indeed, could hardly find sufficient work to keep him constantly employed. It is then more to the interest, at any rate of smaller companies, to employ a professional inspector.

English Engineers' Specifications.—I will now give a few particulars of English engineers' rail specifications and of their mode of inspection, and afterwards some of those adopted on the Continent. The English engineers, both for English and Colonial roads, prescribe very much harder conditions in their specifications than I have thought necessary to fix in mine; yet I very much doubt whether they get a better result. For instance, they stipulate that the pig iron should be cold-blast, mixed with Swedish, Spanish, and Cumberland hematite, or other suitable cold-blast pig, with a proper quantity of best Rhenish spiegel, and not less than 10 per cent. charcoal pig re-melted in air furnaces, not in cupolas, ingots hammered not bloomed, and then tested with very heavy falling test. For instance, rails should be bent to right angles by blows without breaking (which means that for 56-pound rail three or four blows from a ton ball falling thirty feet are required). Finally the rails have to be chemically analyzed at the direction of the engineer by a professional analyst, to whom the maker has to pay £5 5*s* for each

* Appendix VII, The Straightening of Steel Rails.

sis made. Then follows, in one of them, this sentence: "The after they have been drilled and while warm are to be dipped ot-boiled linseed oil before they have been exposed to the ner, as a protection from the effect of the sea-water, etc., and vards they must be sanded so as to effectually prevent their slip- in the ships on the voyage to their destination.

ese and many other like stipulations simply mean an enhanced from which the railway company derives no corresponding ntage. There are many points in the system of railmaking and ction in England, insisted upon by English engineers, which t well be recorded, but as in my practice I have not had to with them, I may pass on to a short review of the leading fea- of the Continental system.

rman Engineers' Specifications.—Taking the largest district, in Rhenish Prussia, there are about half a score of makers about 10,000 tons weekly output, who formerly made rails for Germany and the Continent, but who now have com- ed exportation to America, because they produce twice as as is required for home consumption. The German engineers really gone to the extreme in specifying tests, to which no rs in other countries would submit. I give *in extenso* three mens of modern German specification in the appendix,* such as ggested by the Minister of Public Works, which therefore car- reat weight, since the government bought some of the principal such as the Berlin-Cologne-Minden, and similar important ays. In fact, Bismarck has laid his hand upon nearly all the lines in the country for political reasons.

om the specifications given it will be seen that over and above rdinary tests there is particular stress laid upon the contraction ea, say 35 per cent., and absolute strength, 80,000 pounds per e inch, with 20 per cent. elongation. Inspection is more strin- rejecting for the slightest crack, and even after this inspection e works, which causes great hindrance in the manufacture, the on arriving at their destination are still liable to be rejected on the d inspection. In the case of acceptance of tender a deposit of 5 ent. is required for 10, and sometimes 12, years from the maker as rantee, but it is simply kept as caution-money. I need scarcely hat for such home orders a higher price is paid, on account of stipulations and the trouble and annoyance they entail, for

* Appendix VIII, German Specifications.

which the railway company certainly does not reap a corresponding advantage. I may, in conclusion, say that in my opinion the German engineers have gone much too far in the stipulation for physical tests. They lay all the stress upon contraction of area, which may, I admit, indicate a soft material, but which test costs a great deal to make, and, what is still worse, delays the whole of the manufacture, keeping the maker in a state of constant suspense, or, to speak figuratively, on his bare knees before the directors of the railway, humbly awaiting the result of the final test, which they themselves institute after the rails have left his works and have already been passed by their own inspector.

As the German makers enter into competition with the English in the exportation of rails to America, I have during the last two or three years had to make inspections for American railroads in nearly all the German works, and I may state that the makers are fully competent to do justice under any ordinary conditions. They have been so much bothered, hampered, and cramped with the extraordinary stipulations of their own railways, that they are pleased to work to a simple specification from abroad, and they much appreciate the relief it affords. The inspection results are good. Straightening is the principal cause of rejection there as in England.

Other Continental Engineers' Specifications.—Belgium has only two works laid out for steelmaking, and France only one,—the Creusot Works,—which competes for foreign orders. I have inspected rails at the latter works, with entire satisfaction, for Scandinavia. It may be here remarked that the specifications for railways in Spain, Italy, and France prescribe a less falling test than other countries in Europe, chiefly on account of the milder climate which there prevails. Russia, however, as the breakage of rails is a source of much trouble to her, has introduced into the specification a falling test under artificial cold, so that the test at the works where the rails are made may agree better with that afterwards made in Russia. The Minister of Railways has lately read a paper before the Iron and Steel Institute, in which are given results of experiments in this direction. A piece of rail is imbedded in a mixture of salt and ice which produces a temperature of minus 20° Fahrenheit; after being cooled down in this mixture the rail has to sustain the ordinary falling test prescribed for steel rails. This seems to be a rather complicated and costly method, besides being slow, and would not therefore suit makers who wish to make their own tests during production, as described above. If, instead of the arti-

l cold, the falling test had been increased in a degree correspond- with the loss of strength due to cold, the same result would e been obtained with fewer drawbacks in the operation. It is e hoped that after satisfactory relationship between the loss of ngth and the lowering of temperature has been ascertained, the nary falling test may be used without salt and ice, but simply be lated according to the temperature prevailing at the time of ng. My own experiments, made nine or ten years ago, on influence of cold show that at low temperatures the diminution trength is considerable,* and the same also appears in the paper before the Institution of Civil Engineers by Webster.† We may lude that there is certainly wanted a more severe falling test for y in rails constructed for cold climates than for those intended nild ones, but we have not yet sufficient data to determine ex- the relationship between test and temperature.

merican Engineers' Specifications.—This finishes the broad ine of my remarks on rail inspection in Europe, and I would now to touch upon the same subject as treated in America. ut a year ago my friend Mr. Holley presented me with a copy Dr. Dudley's work on the Chemical Composition and Phys- Properties of Steel Rails,§ and he asked me to take up the er in Europe. I accepted the task with great pleasure, and rculated a large number of copies of the book amongst the neers and most eminent authorities in Europe, writing a letter each, asking an opinion on the book after perusal, as it con- ed new views upon steel-rail manufacture. I received many ies from all sides, some of which I give in the appendix.‡ I wrote to the learned doctor himself, asking for further informa- on the subject, and received a reply saying that he was con- ing his researches, the result of which would be laid before the itute. This year I have had to inspect rails made under Dr. ley's specification, and it so happened that Mr. Holley was then he district. They were made in Germany; the quantity was 0 tons, which sufficiently, I think, entitles me to advance an ion. I need not repeat what has been already said in the ex- nt discussion which took place at your Institute, which I

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*See Appendix to translation of Styffe's Experiments on the Strength of Iron at Different Temperatures.

†Webster on Iron and Steel at Low Temperatures, 1879–80.

‡Appendix IX. Opinions on Dr. Dudley's Paper.

§Transactions American Institute of Mining Engineers, Vol. VII.

regard as being one of the most able and instructive discussions held for many years. It was only after great consideration that both the makers and myself would undertake the execution of the specification. The small amount of silicon seemed to be the point of difficulty; however, by making the pig iron so as to start with only 1½ per cent. of silicon we brought it to its specified quantity of .04 or less in the rail, and we worked to all the other conditions closely. The results were, in rolling, more wasters and a larger quantity of rejections through the metal being less fluid than usual, the ingots were not so solid, and the rail-ends showed honeycombs and blisters. For these reasons I believe that rails made with this chemical composition will show unsoundness and will not wear as well as ordinary steel rails. We know that silicon is used even in casting gun metal with the object of obtaining solid ingots to commence with, and the strength wanted is obtained afterwards by hammering and other manipulations. Why should it then be excluded from the rail metal, when solidity in the rail is of equally great importance as in guns? I admit that an excess of silicon is objectionable on the score of safety, but I would not consider it too high unless the quantity rises to 0.12 per cent., or more than three times as much as Dr. Dudley allows, provided that the other hardening substances are in accordance with Dr. Dudley's formula. However, a complete analysis was made by my own chemist, Mr. Troilius, in conjunction with the chemist at the works in question, and the results of their analyses on the same boring, taken at random from the steel, agreed perfectly. These results I have entered in the inspection book in the ordinary way. Five analyses were made, and I kept the boring used in each analysis, in case any dispute should arise. I am pleased that I have had the opportunity of inspecting an order made under Dr. Dudley's formula and specification in all respects. I have been thus enabled to draw practical conclusions, and I think that the specification can, with great care in mixing the pig iron, be carried out, but I find that the cost is a great deal higher than in the ordinary working. In my opinion the course followed is not altogether desirable, as the results in the end are not as good as in the ordinary methods. However, if railway companies will insist upon adopting this specification, I can see it carried out.

I hope that the investigations and researches which Dr. Dudley has commenced will be continued by others as well as himself. For my part I will do my best in Europe, and I believe that I may flatter myself as being actuated by the same feeling as Dr. Dudley,

to ultimately arrive at the best specification for steel rails. one could value the assistance of chemistry in steelmaking e than myself, and I may say that I started the chemical labo- ry at the Crewe Steel Works, on the London and North- ern Railway, about eleven years ago, but I do not hesitate to rse the expressions of my friend Dr. Percy, the greatest chem- authority on iron and steel in England, when he says: "Let be satisfied with ordinary physical tests, and take to chemistry for explanations when any extraordinary results are obtained." hese words lies the truth; let the chemist *help* us, but not be er and dictator. Again, why should only one chemical compo- n be thought to be the right one. Rails may vary greatly mposition, and yet be equally good in wear, and if only one ula be specified competition in tendering would naturally be ced, and would cause unnecessarily high prices.

nclusions.—Finally, we may look at the general experience re- ng from the use of iron and steel rails. In 1868 I believe I laid the results on a large scale before the railway world in a paper on the ufacture and wear of rails, read before the Institution of Civil ineers in England.* Since that paper was written the favorable ion then expressed as to steel rails has only been strengthened, and e price of such rails has been reduced, rails made of iron have been st entirely superseded in the market. Railways on which there enormous an amount of traffic as on some in England, like the opolitan Railway, for instance, would never have been able to tain their system, and meet the requirements of such a large ser- of trains, if they had not been laid with steel rails. On the Con- t the same remark applies with almost equal force. One of the frequented lines in Germany, the Cologne-Minden, which has been wholly laid in steel for the last seven years, gives the fol- ng result in comparison with the former use of iron rails. They erly had an exchange of 7 per cent. per annum of the iron rails ch were, by the way, much superior to those now ordinarily em- ed in England), but during the seven years' wear of the steel there has not been so much as 1 per cent. replaced. What proof, then, is needed? Similarly good results are obtained in ce, and all over Europe, and as for cold climates, such as Scan- ia, Russia, and Canada, steel is certainly more safe in point of gth than the iron rails. Therefore I see no reason why steel of ordi-

* Sandberg on the Manufacture and Wear of Rails, 1867–68.

nary quality should not be used in America. The investigations on the Pennsylvania Railroad must have been made under exceptional conditions, for I see no reason why they should give different results from those obtained elsewhere. It is true that the way in which steel rails sometimes break is startling, and makes one suspicious; but I can safely say that there were more accidents caused by the lamination of iron rails formerly than there now is from fracture of steel rails. I may give figures derived from official reports of the railway recently referred to, where, even with the greatest care in inspection and maintenance of road, fractures of the steel rails have occurred in the seven years during which they had been laid, in no fewer than 1400 cases; but, notwithstanding this, there has been no instance of the engine or train running off the line. We must conclude from this that the breakage of steel rails is not necessarily of a destructive or dangerous nature, if the lines are only watched by the plate-layers and railway inspectors. There are actually at the present time in England hundreds of miles of old branch lines without any fish plates at all, which might be compared to broken rails; still traffic is safe, though necessarily slow.

I will in conclusion refer to a single instance of a broken rail, which only by some singularly good fortune failed to cause an accident (I give a drawing of it in the appendix*). The rail broke on 26th December last near Cologne, under the Berlin Express, in no less than seventeen pieces. It had been in service for six years, and no signs of failure had been observed. When it was analyzed it was found to be of almost exactly the same composition as that which Dr. Dudley recommends, and the steel of the broken pieces conformed to his tests. This shows that exceptional fractures of steel rails will occur under all circumstances, but the number of failures is not nearly as great as happened when iron rails were used in former times. The long and short of the whole matter is that we now get steel rails without increased price, and with many times the amount of endurance and safety, which was previously the case with iron rails.† The railway world has made great advances in rail production to the advantage of all concerned, and I hope this will continue to be the case. It is far from my wish that supervision should be in any way lessened. Yet, on the other hand, I cannot advise my clients and the consumers generally to place much weight

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* Appendix X, Drawing of Broken Rail.

† See Appendix XI, Sandberg's Diagram of Average Prices of Iron and Steel Rails since 1854.

uselessly strict specifications, but rather to be satisfied with only t is really necessary. America in her growing rail manufacture feel the need of inspection more and more, as we have done in ope, but I hope that the error into which we have fallen of ifying too much will be avoided, and it is with this in view that ve stated frankly my opinion and given my reasons for it, based the results of practice. No country has honored me with so h confidence in the rail inspection as America, and I therefore a strong desire, as a token of gratitude, that my remarks should aken to heart and considered carefully for the benefit, as I hope, e country at large.

APPENDICES TO SANDBERG'S PAPER ON RAIL INSPECTION.

APPENDIX I.

TRACT FOR RAILS AND FASTENINGS—TONS OF RAILS WITH FISH-PLATES, BOLTS, AND NUTS.

Sandberg's Form of Specification for Iron Rails.

ction.—The rails are to be of the section shown in the annexed ving inches high and inches on the base. mplate will be handed with the order.

Veight.—The rails are to weigh pounds per yard. The l allowance of 2 per cent. on single rail, and 1 per cent. on total ntity will be accorded without rejection, but the rails must not nvoiced at more than pounds per yard, and makers will nswerable for the full weight as per invoice.

ength.—The length of the rails is fixed to feet Eng- with an allowance of inch above or below this measure. per cent. of the total quantity may be of shorter lengths, only

unching and Notching.—Each end of every rail must have two oles for the bolts and notches cut in the flange ccordance with tracing handed with the order.

Marking.—Each rail must bear the name of the maker, and the in which it is rolled. The letters must be distinct, and at least inch in height. Each rail, when inspected and approved, must

be stamped with the private stamp of the inspecting engineer. The rails will not be accepted unless this has been complied with.

Mode of Manufacture.—The rails are to be made from a pile of sound and compact iron. This pile shall consist of a top slab of inches thick, and 2 layers of puddle bars next to it. The arrangement of the remainder of the pile is left to the option of the manufacturer. The rail pile is to be heated twice, and rolled into a rail of exact section. The top slab shall be made from puddled iron only of hard crystalline texture, such as will effectually withstand the action of traffic without laminating, crushing, or breaking. All rails bearing evidence of defective welding will be rejected. The rails must be perfectly straight and smooth, without cracks or flaws. The ends are to be cut square off, and at right angles to the base, and the cut end must show a surface smooth, clean, compact, and without defects.

Inspection.—The rails will be passed in lots not exceeding 1000 bars each. The engineer or inspector appointed by the buyer will select from each lot a certain number of rails, not exceeding ½ per cent. of the whole, and will test them as follows:

Tests.—1st. Each of the selected rails must carry tons in the centre, between 3 feet bearings, for five minutes, without permanent set.

2d. The rails must carry in the same position a load of tons without breaking. After this the flange of the rail will be cut, and the rail broken. The fracture must show perfect welding, especially in the head.

3d. Each half of the broken rail again placed on 3 feet bearings must stand a blow from a ball weighing falling from a height of feet on the rail between the supports without showing any fracture. The bearings are to be of cast iron fixed on oak frames, and supported on solid masonry 4 feet deep.

Should one of the rails fail under any of the above tests, the lot will be divided into ten equal portions, and one rail from each will be tested. Each rail then proving unequal to the test will cause the lot from which it was taken to be rejected.

The inspector of the company is to have the right of entrance to the works at all times to inspect the manufacture and quality of the materials, and to superintend the testing of the rails; but this inspection is in no way to remove the responsibility of the manufacturer, who is bound to deliver nothing but good sound rails of best workmanship and good materials. Any remarks which the in-

or may have to make are to be addressed to the manager of the
s, and not to the workmen therein employed. All rails in-
ed, approved, and stamped by the inspecting engineer cannot
wards be rejected.

sh-plates.—The fish plates are to be inches long, and of
xact section shown in the drawing annexed. They are to be
e of good strong iron that will stand bending, and to be per-
straight and smooth on every surface, and well squared off at
ends. The fish-plates are to have four (4) holes inch
hed in them, to correspond with the holes in the rails as per
ing. The number of fish-plates is to be two (2) for every rail,
they are to be bundled together, ten in each bundle.

olts.—The bolts for the fish-joints, inch diameter, con-
able to drawing annexed should be made of good strong iron
will stand bending; the heads to be worked out of the solid,
not welded. The forging to be perfectly sound and true. The
ad to be Whitworth's, cut clean and full. The number of the
is to be four (4) to every rail. Bolts and nuts to be packed
rong cases, sufficiently secure for sea voyage and transport by
.

Sandberg's Form of Specification for Steel Rails.

ction.—The rails are to be of the section shown on annexed
ing, inches high, and inches on the base, and to be
e according to a template which will be furnished with the order.
he rails are to be perfectly straight and true, and of uniform
on throughout their whole length.

Veight.—The rails are to weigh pounds per yard. The
l allowance of 2 per cent. on single rail, and 1 per cent. on total
ntity will be accorded without rejection, but the rails must not
nvoiced at more than pounds per yard, and makers will
nswerable for the full weight as per invoice.

ength.—The length of the rails is fixed to feet
es, with an allowance of inch above or below this measure.
per cent. of the total quantity may be of shorter lengths
only

rilling, Punching, and Notching.—

Marking.—Each rail must bear the name of the maker and the
in which it is rolled. The letters must be distinct so as to
tify the rails. Each rail when inspected and approved must be
ped with the private stamp of the inspecting engineer. The
will not be accepted unless this has been complied with.

Mode of Manufacture.—The steel must be cast into ingots by the Bessemer or Siemens process, and must be of uniform quality and equal hardness throughout, and the inspecting engineer will be at liberty to test sample ingots by forging, tempering, bending, or otherwise, to satisfy himself of the proper material being used.

These ingots must be heated well through, then hammered or rolled into a rail of exact section. Flaws or cracks in the ingot must be cut out hot before the last rolling so as to make a perfectly smooth and clean rail free from cracks, flaws, and other imperfections. No patching or mending the flanges will be tolerated.

Inspection.—The rails will be passed in lots not exceeding 1000 bars each. The engineer or inspector appointed by the buyer will select from each lot a certain number of rails, not exceeding ½ per cent. of the whole, and will test them as follows:

Tests.—1st. Each of the selected rails must carry tons in the centre, between 3 feet bearings, for five minutes, without permanent set.

2d. The rails must carry in the same position a load of tons without breaking; after this the flange of the rail will be cut and the rail broken. The fracture must show perfect welding, especially in the head.

3d. Each half of the broken rail again placed on 3 feet bearings must stand a blow from a ball weighing fallihg from a height of feet on the rail between the supports without showing any fracture. The bearings are to be of cast iron fixed on oak frames and supported on solid masonry 4 feet deep.

Should one of the rails fail under any of the above tests, the lot will be divided into ten equal portions, and one rail from each will be tested. Each rail then proving unequal to the test, will cause the lot from which it was taken to be rejected.

The inspector of the company is to have the right of entrance to the works at all times, to inspect the manufacture and quality of the materials, and to superintend the testing of the rails; but this inspection is in no way to remove the responsibility of the manufacturer, who is bound to deliver nothing but good sound rails of best workmanship and good materials. Any remarks which the inspector may have to make, are to be addressed to the manager of the works, and not to the workmen therein employed. All rails inspected, approved, and stamped by the inspecting engineer, cannot afterwards be rejected.

Notice of Rolling.—The makers to give eight days' notice to the inspecting engineer of commencing the rolling, and not less than

days' notice of resuming the work after its temporary sus-ion.

APPENDIX II.

DESCRIPTION OF SANDBERG'S STANDARD RAIL SECTIONS.

(*See cuts of rail sections on accompanying plates.*)

bject of Design.—(1.) To economize metal, and secure a strong durable road by improved form of rail and fish-joint.

.) To combine the requirements of the engineer with those of manufacturer, avoiding unnecessary cost through complicated gns and specifications.

.) To introduce standard patterns into general use, thereby ring uniformity, and facilitating constant manufacture at slack s, thus avoiding extreme fluctuations in the rail market when a en demand exceeds production.

escription of Rail Sections.—The rails are designed with the and height of equal dimensions, except in the lighter forms, as 20 to 45 pounds, calculated for lower speeds, where the height creased ¼ inch, thereby increasing the stiffness of the rail.

or every 5 pounds additional weight per yard ¼ inch is added e height and width (see Table No. 1), and at the same time a ortionate increase in wearing substance is provided for.

ne angles of the rail in contact with the fish-plate are the same and bottom—11° in the heavy sections, 15° in the lighter rails. fish-plates are therefore reversible, and form so firm a joint it can be loaded with two-thirds of the weight, which the rail carry in the middle without taking permanent set (see Table 1).

escription of Road.—These rails can be laid direct without base-s, on ordinary cross sleepers, 3 feet from centre to centre and 2 at the joint. Sleepers to rest on good ballast, and the road well ned. Table No. 1 shows weight of rails required per English single line. For fishing and fastening of each rail section full culars are given in Table No. 2. Notching for suspended joint nches on one side, 12 inches on the other from rail-end to com-cement of notch, and for rail-joint laid on sleeper 2 inches from end on both sides.

escription of Rolling Stock.—Table No 1 shows the stiffness and gth of each rail, also *maximum* weight of engine or safe load, h is, however, not the most economical for working a line, but s the ultimate safe load to which an increase of traffic may extend.

The weight on each wheel of carriages and trucks may approach but not exceed the safe load on engine-wheel.

Maximum Speed to be Used.—The heavy sections, 50 to 80 pounds per yard, are designed for ordinary speeds—say 25 miles per hour for goods, and 40 miles per hour for passenger traffic. The sections 35 pounds to 45 pounds are for lower speeds—say 15 miles per hour for goods, and 25 miles per hour for passenger traffic. The sections 20 pounds to 30 pounds (intended chiefly for private lines) are calculated for a speed of 10 miles per hour; and rails of 15 pounds are only fit for horse traction.

Guide to Specification for the Manufacture of Iron Rails of Extra or Superior Quality.—Table No. 1 gives dimensions of top slab for rails according to weight per yard. The rail pile to be heated twice.

The rail to be tested for safety by falling weight, according to the following rule:

Weight of ball in cwts. × height of fall in feet to equal weight of rail per yard in pounds; for instance, 7 cwt. falling 8 feet for 56-pound rail. The rail to rest on solid supports three feet apart. The rails to stand the tests by dead weight indicated in Table No. 1. The wearing capacity to be ascertained by daily experiments made by inspector during manufacture. These tests for safety and wearing qualities of the rail may vary, not only according to the weight of the rail, but also to local conditions, such as climate, nature of road, and traffic, for which reason a complete specification adapted to all cases cannot be here given.

Advantages of these Rail Sections, as Compared with those Ordinarily Used.—(1.) Greater stability and safety of road through increased width of rail base.

(2.) Uniform stiffness of the road by greater strength at the rail-joint than can be obtained with the plain fish applied to ordinary pear-shaped rail sections of greater inclination for the fish-plate than requisite for easy rolling, which may be taken at 11° for heavy sections and 15° for light rails.

(3.) Increased traffic capacity on these sections by the use of heavier engines in proportion to the weight of the rail than can be employed on ordinary sections (see Table No. 1).

(4.) Cheap maintenance of the permanent way by the increased rail-base saving the sleepers, and the joints kept tight by less work being thrown upon the bolt than in the pear-formed section of greater inclination in the fishing angle.

SHOWING WEIGHT, DIMENSIONS, AND CAPACITY OF SANDBERG'S STANDARD RAIL SECTIONS.

Sandberg's standard sections. Weight of rail per yard. Pounds.	Dimensions of top slab for rails of extra quality.	Height of rail. Inches.	Base of rail. Inches.	Speed in miles per hour.		Strength. Dead weight. Breaking load in tons on rail, 3 feet solid supports.	Stiffness. Dead weight in tons on rail, 3 ft. solid supports, without permanent set.	Stiffness. Dead weight in tons on *rail-joint*, 2 feet supports, without permanent set.	Maximum load in tons on each driving-wheel for ordinary goods engine	Traffic capacity. Maximum weight of engines in tons, ordinary goods engine.	Weight of rail in tons required per English mile of single line.
				Goods traffic.	Passenger traffic.						
15	4½″ × 1″	$1\frac{15}{16}$	$1\frac{15}{16}$								23
20	4½″ × 1½″	2½	2¼	10		4	2.0	1.3	1.0	5.0	31
25	4½″ × 1½″	2¾	2½	10		6	3.0	2.0	1.5	7.5	39
30	6″ × 1½″	3	2¾	10		8	4.0	3.0	2.0	10.0	47
35	6″ × 1½″	3¼	3	15	25	13	6.5	4.0	3.25	16.0	55
40	7″ × 1½″	3½	3¼	15	25	16	8.0	5.2	4.0	20.0	62
45	7″ × 1½″	3¾	3½	15	25	19	9.5	6.3	4.75	23.75	71
50	7½″ × 1½″	3¾	3¾	25	40	22	11.0	7.3	5.5	27.5	78
56	8″ × 1½″	4	4	25	and upwards.	25	12.5	8.2	5.87	31.0	88
60	8″ × 1½″	4¼	4¼	25		28	14.0	9.2	6.25	35.0	94
65	8½″ × 1½″	4½	4½	25		31	15.5	10.2	6.62	38.75	102
70	9″ × 1½″	4¾	4¾	25		34	17.0	11.2	7.0	42.5	110
75	9″ × 1½″		5	25		37	18.5	12.2	7.25	46.0	117
80	9″ × 1½″	5¼	5¼	25		40	20.0	13.2	7.5	50.0	125

TABLE NO. II.

SHOWING RAIL-LENGTHS AND FASTENINGS FOR SANDBERG'S STANDARD RAIL SECTIONS.

	LIGHT RAILS.			HEAVY RAILS.		
	Rails. 20 and 25 pounds per yard.	Rails. 30 and 35 pounds. per yard.	Rails. 40 and 45 pounds. per yard.	Rails. 50 pound per yard.	Rails. 56, 60, and 65 pounds per yard,	Rails. 70, 75, and 80 pounds per yard.
Holes in rails for fishing	$\frac{7}{8}$″ × $\frac{5}{8}$″ oval	1″ × $\frac{3}{4}$″ oval	1$\frac{1}{8}$″ × $\frac{7}{8}$″ oval	1″ × 1$\frac{1}{4}$″ oval	1$\frac{1}{8}$″ × 1$\frac{3}{8}$″ oval	1$\frac{1}{4}$″ × 1$\frac{1}{2}$ oval
	2 holes at each end. Centre of first hole 1$\frac{1}{16}$″ from end of rail. Centre of second hole 3$\frac{1}{2}$″ from centre of first.			2 holes at each end. Centre of first hole 2$\frac{3}{16}$″ from end of rail. Centre of second hole 4$\frac{1}{2}$″ from centre of first.		
Holes in fish-plate for bolts	$\frac{5}{8}$″ diameter	$\frac{3}{4}$″ diameter	$\frac{7}{8}$″ diameter	$\frac{7}{8}$″ diameter.	1″ diameter	1$\frac{1}{8}$″ diameter
	Fish-plates 13″ long. Four pear-shaped holes. 3$\frac{1}{2}$″ between centres in each plate.			Fish-plates 18″ long. Four pear-shaped holes. 2$\frac{1}{4}$″ centre of first hole to end of fish, 4$\frac{1}{2}$ from centre to centre.		
Bolts and nuts, pear-shaped bolts	$\frac{1}{2}$″ diameter	$\frac{5}{8}$″ diameter	$\frac{3}{4}$″ diameter	$\frac{3}{4}$″ diameter	$\frac{7}{8}$″ diameter	1″ diameter
Spikes, dog spikes	4″ long × $\frac{3}{8}$″ sq.	4$\frac{1}{2}$″ long × $\frac{7}{16}$″ sq	4$\frac{1}{2}$″ long × $\frac{1}{2}$″ sq.	5″ long × $\frac{1}{2}$″ sq.	6″ long × $\frac{9}{16}$″ sq.	6″ long × $\frac{5}{8}$″ sq.
Notches, for spikes in flange of rail	$\frac{3}{4}$″ × $\frac{1}{4}$″	$\frac{3}{4}$″ × $\frac{1}{4}$″	$\frac{3}{4}$″ × $\frac{3}{8}$″	$\frac{3}{4}$″ × $\frac{3}{8}$″	$\frac{7}{8}$″ × $\frac{3}{8}$″	$\frac{7}{8}$″ × $\frac{3}{4}$″
Length of rails, with 10 per cent. short rails in even feet	18′ standard. Shorts, none under 12′	21′ standard. Shorts, none under 15′	21′ standard. Shorts, none under 15′	24′ standard. Shorts, none under 18′	24′ standard. Shorts, none under 18′	24′ standard. Shorts, none under 18′

CIFICATION FOR LIGHT RAILS WEIGHING FROM TWENTY TO FORTY POUNDS PER YARD.

CONSTRUCTION OF SECTIONS.

eight yard.	Height.	Base.	Width of head.	Thickness of edge of flange.	Thickness of stem.	Dimensions of top slab used for extra rails.
lbs.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
45	3¾	3½	2	9/16	7/16	7 × 1¼
40	3½	3¼	1⅞	1/2	7/16	7 × 1¼
35	3¼	3	1¾	1/4	3/8	6 × 1½
30	3	2¾	1 11/16	1/4	5/16	6 × 1½
25	2¾	2½	1 5/16	7/32	1 1/32	4½ × 1⅛
20	2½	2¼	1⅜	3/16	5/16	4½ × 1½

E.—The sections are increased ¼ inch in height and base for every 5 lbs increased weight rd. Fish-plates reversible in contact with head and flange of rail at an angle of 15°.

ength of Rail.—Standard length to be 21 feet, with 10 per cent. 8, 15, and 12 feet, with allowance not exceeding ¼ of an inch under ver these specified lengths.

Punching, Notching, and Fastenings.—

	RAILS. 45 & 40 lbs. per yard.	RAILS. 35 & 30 lbs. per yard.	RAILS. 25 & 20 lbs. per yard.
es in rail oval.....	1⅛ × ⅞	1 × ¾	⅞ × ⅝
	2 holes at each end.	Centre of 1st hole. 1 1/16 from end of rail.	
		" 2d " 3½ from centre of	
		first in all the sections.	
es in fish-plate, pear shaped.	⅞ in. diam.	¾ in. diam.	⅝ in. diam.
	Fish-plates 13 in. long in all the sections. 4 pear-shaped holes 3½ in. between centres in each plate.		
s and nuts. Cuphead square ls, pear shaped necks.....	¾ in. diam.	⅝ in diam.	½ in. diam.
es.....	1½ in. long × ½ in. sq.	4½ in. × 7/16 in. sq.	4½ in. long × ⅜ in sq.
ches for suspended joints 9 nches from end of rail.....	¾ in. × ⅜ in.	¾ in. × ¼ in.	¾ in. × ¼ in.
ches. Where joint lays on eeper 2 inches from end of il.....	¾ in. × ⅜ in.	¾ in. × ¼ in.	¾ in. × ¼ in.

Mode of Manufacture.—The rail shall be made from piles of 7 nes square for the 45 and 40 pounds, 6 inches square for the 35 and pounds, and 4½ inches square for the 25 and 20 pounds, or from s of a corresponding sectional area. These piles shall be laid up h a top slab of No. 2 iron, of hard crystalline texture, perfectly nogeneous, and puddle bars arranged so as to break joint. The

pile to be heated and bloomed between rollers, reheated, and then rolled into a finished rail. The thickness of the top slab shall be not less than 1½ inches by the widths above specified, or corresponding dimensions, so as to produce a thickness of wearing surface in the head of the finished rail of not less than ½ inch.

Testing for Strength or Safety.—Rails supported at 3 feet distance on a solid iron block in masonry shall sustain, without fracture, falling weights in proportion to the weight of rail without sign of fracture, viz.: 5 cwt. ball falling 9 feet for the 45-pound, 8 feet for the 40-pound, 7 feet for the 35-pound, 6 feet for the 30-pound, 5 feet for the 25-pound, and 4 feet for the 20-pound rail.

One rail out of every 1000 must be tested, and if not broken the whole 1000 will be accepted; but if unequal to the test, a further 10 rails must be tested from the same make, and for each of these standing such a test 99 will be accepted.

Test of Welding in Rail-head.—The rail shall be nicked under the flange and broken, with the head upward, when it must show perfect welding in the head of the rail, and no seams must be visible in the broken section of the head.

Inspection.—The inspector to be present at the works at all times during the rolling, to see that the rails are made to specification, to superintend the tests for strength and welding as mentioned above, in order to insure sufficient strength as well as durability of the rails, and to pass and stamp each rail approved of before it leaves the works. The inspector to be appointed and paid by the railway authorities, and to furnish them with weekly reports on the progress of the manufacture, and the results of his examination.

In the inspection of *ordinary iron rails* the mode of manufacture is left entirely to the makers; but the inspector is entitled to test the rails as to safety and exterior correctness, so as to be able to certify that they are safe to run on, and can be laid without difficulty; but the rails are not to be stamped as *extra*, and only certified as an *ordinary merchantable rail.*

Comparative Value of Rails of Different Sections.—The requirements of the different parts of a rail section, such as base, stem, and head, depend upon the work the rails have to perform. As light railways have proved a success in many countries, the want of good standard sections for light rails from 45 pounds down to 20 pounds per yard is obvious. Standard sections of heavier weights have been already published. Less speed and lighter traffic being expected from light roads, the principle of making the base equal to the height of the rail (adopted in the case of heavy sections) can be

fied; increased stiffness by increase of height is in this case necessary. The annexed standard sections for light rails have designed with ¼ inch less width of base than height, the head ghtly reduced, the stem and the flange reduced as thin as com-le with easy rolling.

e fastenings are somewhat lighter than adopted for standard ns for heavy rails. The weight of the sections is reduced 5 ds per yard for every quarter of an inch of reduced width and t, starting with 3¾ inches by 3½ inches for 45 pounds down to 2½ s by 2¼ inches for 20 pounds. Intermediate sections graduating h for every 2½ pounds per yard can easily be designed on the principle. These sections possess sufficient wearing surface in

RATIVE CAPACITY AND COST OF RAILS FOR LIGHT RAILWAYS.

2ft. 6 in. supports without permanent set.	COST OF METAL FOR ONE ENGLISH MILE SINGLE LINE F. O. B. ENGLISH PORT.				Total cost at present prices, Oct., 1871.
	RAILS.	FISH-PLATES.	BOLTS AND NUTS.	SPIKES.	
Tons.	T. C. Q. lbs. £ s. d.	T. C. Q. lbs. £ s. d.	T. C. Q. lbs. £ s. d.	T. C. Q. lbs. £ s. d.	£
10½	71 14 1 4 at 7 7 6	2 5 2 5 at 8 10 0	0 18 0 0 at 15 0 0	1 17 0 0 at 14 0 0	588
9	62 17 0 16 " 7 7 6	2 3 0 17 " 8 10 0	0 18 0 0 " 15 0 0	1 17 0 0 " 14 0 0	521
7½	55 0 0 0 " 7 12 6	2 0 3 1 " 9 0 0	0 12 0 0 " 17 6 0	1 9 0 0 " 15 0 0	470
5	47 2 3 17 " 7 12 6	1 8 3 2 " 9 10 0	0 11 0 0 " 17 6 0	1 9 0 0 " 15 0 0	405
3½	39 5 2 24 " 7 15 0	1 6 1 14 " 10 0 0	0 7 0 0 " 20 0 0	0 19 0 0 " 17 6 0	341
2	31 8 2 8 " 7 15 0	1 3 3 26 " 10 0 0	0 6 2 0 " 20 0 0	0 19 0 0 " 17 6 0	279
10½	96 0 0 0 " 7 0 0			1 17 0 0 " 14 0 0	698

ead, provided the extra quality is secured by proper specifica- and inspection and the flanges possess sufficient width to insure lity. The accompanying table shows what these standard sections carry in dead weight before taking permanent set as compared the old Erie section. The Erie pattern of 61 pounds per yard s no more advantages than the annexed 45-pounds section, and make a weaker road, not being fished. The same table shows the cost of metal for one mile of single line of the different sec- according to the present market price, allowing 7*s.* 6*d.* per ton for the 45-pound standard section than for the Erie. The er sections are calculated at an increased price. The Erie pat-

tern, without fishing, cost £110 per mile more than the mile laid with the 45-pound standard section, showing a saving of £1 10*s.* per ton on the standard pattern, and there can hardly be a question that the light 45-pound rail will make as good, if not a better road. This only shows the importance of designing sections suitable for the work they have to perform, instead of adopting the cheapest form manufactured.

The principal advantages of using properly designed sections may be summoned up thus: Cheapness, increased durability, and therefore safety and decreased cost of maintenance, not to speak of the saving in cost of transport from the seat of manufacture. In order to secure a good road, strong joints are indispensable. With the simple and inexpensive fish ordinarily used, the form of the rail section is of the greatest importance.

These new standard sections have been designed with the view of securing the greatest possible depth and grip in the fish-plate compatible with easy manufacture, and are founded on the experience obtained in the inspection of the light rails for the Scandinavian railways. With the ordinary pear-shaped form of rail-head, the shoulders offer no resistance to the fish-plates; the difference of angles in the shoulder and foot of the rail will not admit of a reversible fish-plate. The effect is that the joint of these sections will only carry a load of say one-third of what the rail will carry in the middle of its length for the same deflection.

The standard sections will carry at the joint two-thirds of the load they will carry in the middle of their length. Increased safety and great economy in rolling stock is the result of a good continuous road.

For instance, the standard section, 40 pounds per yard, is calculated to carry 9 tons in the middle of its length 2 feet 6 inches bearings, and the joint 6 tons, but as the sleepers are not so firm as the supports in a testing machine, the rail in the road should only be loaded with from $\frac{1}{2}$ to $\frac{2}{3}$ of this latter stress, varying according to the distance between the axles, say from 3 to 4 tons per driving-wheel, or 6 to 8 tons per axle. The weakness of road at the joint can to some extent be compensated by laying the sleepers closer, say 1 foot 6 inches between centres, for which the rails are notched, and gradually increasing the distance to 2 feet 9 inches in the middle. Where the joint is supported the notches are 2 inches from end of rail requiring a stouter sleeper, but on the Swedish and Norwegian railways the suspended joint is preferred.

APPENDIX III.

EFFECT OF NOTCHING.*

TABLE NO. I.

ENGLISH STEEL RAILS.

s made with 57-pound Flange Rails of Bessemer Steel to Ascertain e Loss of Strength against Impact through Notching the Flanges.

RAILS WITHOUT NOTCH.				SAME RAILS TESTED IN THE NOTCH.			
ail o.	Weight of ball.	Height of fall.	Deflection.	Weight of ball.	Height of fall.		Result.
	cwt.	feet	inches.	cwt.	feet,	inches	
1	10	20	5	10	5		broke
2	"	"	4 3/4	"	4		stood
3	"	"	4 7/8	"	4	6	stood
4	"	"	4 3/4	"	5		broke
5	"	"	4 1/4	"	4	6	broke
6	"	"	4 1/4	"	4		stood
7	"	"	4 3/4	"	4		stood
8	"	"	4 1/8	"	4	6	stood
9	"	"	5	"	5		broke
0	"	"	4 1/4	"	4	6	broke
1	"	"	4 7/8	"	4		stood
2	"	"	4 3/8	"	4		stood

rage Result.—Rail without notch 10 cwt. × 20 feet = 200; rail with notch 10 cwt. × 4 feet = 40. tching weakens the rail by at least 80 per cent.

* From a pamphlet by the author on the Safety of Permanent Way.

TABLE NO. II.

FRENCH STEEL RAILS.

Tests made with 66-pound Flange Rails of Bessemer Steel to Ascertain the Loss of Strength against Impact through Notching the Flanges.

Distance of supports.	RAILS WITHOUT NOTCH.			Distance of supports.	SAME RAILS TESTED IN THE NOTCH.			REMARKS.
	Weight of ball.	Height of fall.	Deflection.		Weight of ball.	Height of fall.	Deflection.	
ft. in.	cwt.	feet.	inches.	ft. in.	cwt.	ft. in.	inches	1. Square notch, machine-made 1 inch long × 1/4 in. deep, sharp corners.
					4	1 7	broke	
					"	1 7	broke	
3 8	20	10	2 5/8	3 3	"	2 7	broke	
					"	3 3	broke	
3 8	20	10	2 5/8	3 3	4	1 7	stood	2. Similar notch to above but with inner corners rounded.
					"	2 3	stood	
					"	2 7	stood	
					"	3 3	broke	
3 8	20	10	2 1/8	3 3	8	13 0	1 3/4	3. Half-round notches one inch diameter filed by hand.
					"	"	2 7/8	2d blow
					"	"	"	
					8	13 0	1 7/8	1st blow
					"	"	3 1/8	2d blow

Average Result.—Rail without notch 20 cwt. × 10 feet = 200. 1. Square machine-made notch 4 cwt. × 1′ 7″ = 6 1/2, thus diminishing strength by 97 per cent.; 2. Similar notch with corners rounded 1-16″ radius, 4 cwt. × 2′ 7″ = 10, or 95 per cent. less strength than unnotched rail; 3. Half-round notch 8 cwt. × 13 feet = 104, or 50 per cent. less strength.

TABLE NO. 3.

WELSH IRON RAILS.

ts made with 70-pound Flange Rails to ascertain the Loss of Strength against Impact through Notching the Flanges.

RAILS WITHOUT NOTCH			Distance of supports.	SAME RAILS TESTED IN THE NOTCH.			REMARKS.
Weight of ball.	Height of fall.	Deflection.		Weight of ball.	Height of fall.	Deflection.	
wt.	feet.	inches.	ft. in.	cwt.	feet.	inches.	
			3 6	10	7	1 3/8	1. Notched with 2 notches 1 in. by 5/16 in. not opposite each other.
			"	"	10	2 1/8 cracked.	
10	7	1 3/8 1st blow.	3 6	10	7	1 3/8	2. Notched with 2 same sized notches opposite each other.
"	10	2 2d blow.	"	"	10	broke. "	
			3 6	10	7	7/8	3. Notched with 1 same sized notch only.
			"	"	10	broke. "	

ge Result.—Rail without notch, 10 cwt. × 10 feet — 100. Rails with notch, 1. 10 cwt. × 7 70; 2. 10 cwt. × 7 feet — 70; 3. 10 cwt. × 7 feet — 70.
ing weakens Welsh iron rails 30 per cent.

TABLE NO. 4.

CLEVELAND IRON RAILS.

Tests made with 60-pound Flange Rails to Ascertain the Loss of Strength against Impact through Notching the Flanges.

RAILS WITHOUT NOTCH.					SAME RAILS TESTED IN THE NOTCH.				
Distance of supports.	Weight of ball.	Height of fall.	Deflection.	REMARKS.	Distance of supports.	Weight of ball.	Height of fall.	Deflection.	REMARKS.
ft. in.	cwt.	ft. in.	inches.		ft. in.	cwt.	ft. in.	inches.	
3 6	6	6 6	3/8	1st blow.	3 6	6	5	1/4	1st blow.
"	"	8	1	2d "	"	"	5	broke	2d "
"		10	broke	3d "	"				
"	"	6 6	11/32	1st blow.	"	"	5	broke	1st blow.
"	"	8	broke	2d "	"				
"	"	6 6	5/16	1st blow.	"	"	4 6	3/16	1st blow.
"	"	8	7/8	2d "	"		5	broke	2d "
"	"	8	broke	3d "	"				
"	"	6 6	5/16	1st blow.	"	"	4 6	broke	1st blow.
"	"	6 6	broke	2d "	"				
"	"	6 6	5/16	1st blow.	"	"	4 6	3/16	1st blow.
"	"	8	7/8	2d "	"	"	"	broke	2d "
"	"	8	broke	3d "	"				
"	"	7	3/8	1st blow.	"	"	4	5/16	1st blow.
"	"	8	1	2d "	"	"	5	broke	2d "
"	"	8	broke	3d "	"				
"	"	7	3/8	1st blow.	"	"	4 6	1/4	1st blow.
"	"	7	7/8	2d "	"	"	"	broke	2d "
"	"	7	broke	3d "	"				

Average Result.—Rail without notch 6 cwt. × 8 feet = 48; Rail with notch 6 cwt. × 4 feet = 24. Notching weakens Cleveland iron rails 50 per cent.

The conclusions from the experiments shown by the tables, every railway engineer may see, are:

1st. The necessity of carefully testing the rails for concussion before they are laid, as an engine running over them at 30 to 50 miles per hour will act as impact or shock.

2d. That notching of steel rails (as destructive to the resistance against impact) shall be either entirely abandoned, which may be done when the angle fish-plate is employed, or take place at the corners only.

APPENDIX IV.

INSPECTION BOOK.

DATE 18	Rails Inspected and Rejected for: Bad ends.	Too long rails.	Too short rails.	Crooked rails.	Twist rails.	Bad punching.	Bad rails.	Total rejected rails. No.	Per cent. rejected rails originally.	Percentage of bad rails.	Rails Inspected, Approved, and Stamped with a Crown. Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Total rails.	WEIGHT. Tons.	cwt.	qrs.	lbs.
Brot. forwd.																						
Carried forward																						

Total Rolled Tons. _____
Balance Tons. _____

BALL TEST TO ASCERTAIN THE STRENGTH OF THE RAIL.

Date.	Distance of Supports.	Height of Fall.	Weight of Ball.	Deflection.	Remarks.

FRACTURE TEST TO ASCERTAIN THE WELDING OF RAIL-HEAD.

Date.	Broken under Press.	Broken under Ball.	Nicked on Flange.	Nicked on Head.	Description of Fracture.		Remarks.

EST TO ASCERTAIN THE STIFFNESS OF RAIL BY LEVER.

	Distance of Supports.	Dead weight.	Deflection.		Remarks.
			Temporary.	Permanent.	

TEST TO ASCERTAIN THE SOUNDNESS OF THE TOP SLAB.

Puddle balls.	Rolled.		Thickness of slab. Inches.	Description of fracture.			R marks.
	Edge-ways.	Flat-ways.		Not welded.	Welded.		

APPENDIX VII.

EXTRACT FROM ARTICLE IN ENGINEERING, OCTOBER 10TH, 1879.

WHAT is really wanted is to straighten the rail hot, and this is now done in America by rollers as the rail passes from the saw to the hot bench for cooling. The arrangement consists of three pairs of vertical flat rolls of, say, 1 foot in height and diameter, all placed in a line one after the other, the three on the one side to touch the bottom of the rail, the others on the head, the rail passing through in the same positions as it comes out from the rolls. The rollers are movable horizontally in order to give the rail the required camber to get straight when cooled. The rails rolled to two or three lengths are cut and carried on horizontal rollers till these vertical rollers catch them, taking out all twist, if there be any, and giving the camber required by setting the middle rolls by screws.

The cooling bench, where the rail is placed afterwards, must be perfectly level, as otherwise the rails would bend accordingly, and the result is an almost straight rail when cold, with no twist whatever. It has, of course, to go through the press, but the work is very materially lessened, so that the number of presses or sets of men may be reduced, or the more time bestowed upon doing the straightening better. The advocate of this mode of hot straightening, at least at some rail-works in America, is Mr. Alexander L. Holley, who has done so much to enable the railmakers of the States to hold their own,—we may say almost too much to be agreeable to this side.

On a recent visit to this country, as well as the Continental rail-works, Mr. Holley spoke very warmly on this method, and if asked he would no doubt furnish drawings and detailed descriptions of the arrangements based on his extensive practice in laying out rail works and machinery for their manufacture in America. It would, of course, require longer experience to speak of this method as being perfect to answer the purpose aimed at, viz., a simple method of straightening the rail hot as it comes from the rolls, so that it could be left alone from any rough mechanical treatment cold, save that of drilling the bolt-holes. It is, however, a step in the right direction, and therefore worthy of adoption, or, at least, investigation by European railmakers, particularly if they have to guarantee the rails for ten years.

From the point of view of safety it is of importance, as it treats the rail all through equally, whereby that uniformity of strength so

desired is not spoilt. This is more especially of interest to ailmakers who are compelled to use inferior ores with excess sphorus and silicon. But even to others, who use pure ores, ing a soft steel of a strength that surpasses the most rigid n fact ten times more than is required for its use, it is of in- as a safeguard against occasional hard blows; and to the er it would give a harder and better-wearing rail without fractures. From the point of view of economy it must be a in the manufacture, in the exchange of manual labor to that chinery. The cost of construction of the straightening ap- is but small and amply compensated by saving part of the and labor in straightening cold. The space it occupies is but ompared to the benchroom saved by getting less rails to re- ten and haul from the inspection-benches to the presses. Time saved by turning out more work fit to go at once, by which ck of the rails in the yard is kept low, so that a better control kept by the maker on the progress and execution of each without having to stop to take stock of all rails in the yard estraightened before the balance can be rolled. From every f view it ought to be a saving, and any such, however small ht be, is worth having in these hard times. The immense ss of late in railmaking is best shown by the fact that double antity now produced has not been followed up by a double set ses and men to straighten this increased quantity, and it there- ems that this new method comes to the rescue just at the right nt.

APPENDIX VIII.

GERMAN SPECIFICATIONS FOR STEEL RAILS.

No. 1.

lation of an Extract from the Report of the Minister of Trade and Public Works, Berlin, September 29th, 1878.

Tenders:

Tenders for the delivery of rails should, as a rule, be obtained vertising. The management of the railway is at liberty to or reject any bids. When the rails are urgently needed the may be given directly to a maker selected by the directors, t previous advertisement.

Tests for Quality:

Heavy rails (more than 30 kilos per meter) must, when placed ports 1 meter apart be able to sustain 2 blows from a ball of

600 kilos in weight, falling 5 meters, without fracture or any injury. For lighter rails, as 27.5 kilos per meter, the height of fall is to be reduced to 2.75 meters.

2. Heavy rails, when placed on bearings 1 meter apart, and loaded with 20,000 kilos, and light rails when placed on supports 0.8 m. apart, and loaded with 14,000 kilos, must not show a higher permanent set than 0.25 mm.

3. Heavy rails, when on bearings 1 meter apart, must sustain a deflection on the head of at least 20 mm., and on the flange at least 50 mm., without showing any fracture. All lighter rails must be able to sustain a deflection of 50 mm. on head as well as on flange without cracking.

4. The material for the rails must have, as a minimum, an ultimate tensile strength of 50 kilos per square mm., an elongation of 12 per cent., and a contraction of 20 per cent.

3. *Section and Weight of Rails:*

A variation in length is allowed of $\pm$ 3 mm. and in height of $\pm$ 0.25 mm., and in the width of flange of $\pm$ 1 mm.

No rails will be wanted longer than 9 meters.

The maker may deliver $\frac{1}{20}$ of the order in shorter lengths, subject to an agreement with the company with respect to these shorter lengths.

Rails which are 2 per cent. under weight or 3 per cent. over weight will not be rejected, but the rails in the first case shall be invoiced at the actual weight, and in the second case at not more than 1 per cent. over weight.

The holes in the rails are to be drilled.

4. *Technical Inspection:*

For large orders it is advisable to allow the maker to have the tests made at his works. It is, in such case, required that the inspector appointed by the railway management shall have the right of entrance to the works, and of obtaining any information respecting the manufacture he may deem necessary.

The tests are, as a rule, not to be made on more than $\frac{1}{2}$ per cent. of the order, but may, when required, be made on 1 per cent.

The acceptance of the rails by the railway company takes place at the point of delivery.

5. *Caution Money:*

During the delivery caution money to the extent of 5 per cent. of the amount of the contract shall be deposited by the maker, but after the delivery $2\frac{1}{2}$ per cent. of this amount only shall be required.

6. *Delivery of more or less than the Contract:*

maker agrees to deliver 5 per cent., more or less, of the origi-
ntity at the request of the railway company, when made not
an 4 weeks before the expiration of the time of delivery.
Guarantee:
time of guarantee for the rails is 7 years, beginning on the 1st
uary of the year after the delivery, and is independent of the
eing used at once or not. As a rule those rails which do not
e time of guarantee shall be replaced by new ones, but the
may also pay for them, if satisfactory to the railway company,
ng to the original price if he prefers. The old rails are to be
the disposition of the maker. For the new rails the time of
tee ends at the expiration of the time for the original contract.
se rails are excepted from the guarantee which are notched
eak through the notches; further, those which are damaged by
nts, or by some rough treatment essentially different from or-
wear and tear.
Payment:
rtnight after definite acceptance of the whole order, or a part
he part not to be less than 250,000 kilos), the certificate of
ion is issued, and 6 weeks afterwards payment is to be
or, if not, the reasons for the delay communicated to the
.
Arbitration:
railway management reserves the right to submit differences
may arise to a committee consisting of three persons, one
by each party and the third by the two thus chosen.
en the matter is of but little importance, or for other reasons
ce to one arbitrator is thought best, it is advisable not to select
the royal officials.

No. 2.

Specification of the Berlin-Hamburg Railway.

TION 3. *Section and Length.*—Referred to the correspondence.
4. *Fish-bolt Holes and Notches.*—Every rail is to receive at
nds, for the reception of the fishbolts, two holes, according to
awing handed to the contractor, and exact to template to be
ed to him. These holes must be drilled, and must on no
t be punched. There are not to be any notches in the flange
rail.
5. *Weight.*—The weight of the rail shall be 23.8 pounds per
g foot Rhenish, or 37.9 kilos per meter. An excess weight

of two per cent. is permissible; should, however, a strict adherence to the form and dimensions of the section, which is hereby made an express condition for the reception of the rails, cause a greater difference in weight, such greater excess will not be made good. A deficiency in weight makes the rails unserviceable, and excludes them from acceptance.

SEC. 6. *Place of Delivery.*—Referred to correspondence.

SEC. 7. *Time of Delivery.*—The period within which the rails are to be delivered is specially agreed upon. In case of a delayed delivery the company is empowered to purchase the deliveries in arrears at any price, at the risk and cost of the contractor.

SEC. 8. *Manufacture.*—The rails are to be straight throughout, and must not be warped; they must not show any cracks or any other imperfections; also they must be rolled to the prescribed section throughout the entire length. The ends of the rails must not be cut by means of shears, which flatten the section, but by the saw; moreover the operation may be done at once, and while the rail is in a warm state, if thereby no deviation from the prescribed length of the rail is caused. The cut surface of the rail must be smooth and even, and normal to the axis of the length, and must be freed from all rough edges. After the rails are cut they must not be reheated, and no repairs are allowed either in a cold or in a warm condition.

SEC. 9. *Material.*—The material for the rails must be equal to the prescribed tests, must be faultless throughout, must show no slag and must be thoroughly welded throughout. The fracture must show a homogeneous texture. The material must possess at least a cohesion of 5700 kilos per square cm.,* and a contraction at the point of fracture of at least 35 per cent.

SEC. 10. *Tests.*—The rail, when placed upon the flange and receiving the pressure on the head, must sustain, without cracking or breaking, a curvature of one-twentieth of the free-lying length, also of 50 mm. with the bearings 1 m. apart. With increased loading the fracture must not occur suddenly. With a dead weight of 15,000 kilos upon the middle, between bearings 1 m. apart, there must be no permanent set after the weight has been on several hours. The rail must also allow of being bent permanently sideways, while cold, to a radius of 50 meters; also, when thrown from a height of 5 meters upon a hard surface, the rails must suffer no damage.

SEC. 11. *Reception.*—Referred to the correspondence.

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* 81,070 pounds per square inch.

c. 12. *Control of the Manufacture.*—The railway company is wered to appoint an inspector who will have the right to be nt at all the processes, and to test the rails as required, for n purpose all requisite tools, etc., are to be placed at his disposal. ld one rail out of a rolling not stand the conditions required spector will reject the whole rolling, and no more rails may be l out of material of the same preparation. The contractor must er conform to any representations of the inspector regarding the or length of the rails.

c. 13. *Marking.*—The rails must all bear the year of manufac- and the maker's name.

c. 14. *Guarantee.*—Within ten years from the date of the laying rails, all rails which break or show defects such as in the opinion e officer render them unserviceable, in consequence of the ordi- traffic, and not on account of accidents such as collisions, are replaced in this manner by the contractor, viz., by payment to ompany of the difference between the value of the old rails and ails. For the estimation of this difference the worth of the will be determined according to the price which the railway any pay for new rails and receive for old ones in the year when xchange takes place.

c. 15. *Determination of the Rails to be Replaced.*—A register of ails having to be replaced within the guaranteed time will be in the technical bureau of the railway, and the contractor nizes such as indicative of the replacement to be made by him. contractor has the right to make a survey of the rails.

c. 16. *Decision of Disputes.*—The decision whether the rails are cordance with the prescribed conditions, and therefore deliver- and whether the rails to be exchanged are unserviceable, and fore to be replaced at the cost of the contractor, rests with the ctor intrusted with the reception and the exchange. Disputes een him and the contractor will be decided by the technical or of the railway company finally.

c. 17. *Caution Money.*—For the punctual fulfilment of the obli- ns undertaken the contractor has to deposit, as security, five per of the amount of the contract. If the deposit is made in interest- ng securities the bonds are to be deposited, not the coupons. repayment of the deposit, in so far as the same has not been ted, will be made after the expiration of the guarantee. If the gement, during the course of the guarantee, consider a further it necessary, the contractor must make the deposit within four- lays.

No. 3.

Specification of Steel Rails for Berlin-Potsdam-Magdeburg Railway.

Length.—7.532 m., variation 2 mm., 5 per cent. of shorter lengths not less than 4.708 m.; also a certain quantity of 7.494 m. for curves. All rails differing from the normal lengths are to be paint-marked in a uniform manner, so that their length may be readily distinguished.

Drilling.—The fish-bolt holes must be drilled. The ends of the rails are to be cut by means of a saw and not sheared.

Tests.—1. The rails must sustain a weight of 400 cwt. on bearings 1 meter apart for several hours without any permanent deflection.

2. In a similar manner the rail placed on the flange is to be bent 8 centimeters and not show any cracks or defects.

3. The steel must be hard but not brittle, and tough, and must possess a minimum breaking-strain of at least 5500 kilos per square cm., and a minimum contraction of at least 35 per cent. of the original section.

One rail in each hundred may be broken in order to prove the possession of these qualities.

Other tests, viz., with the falling weight, etc., will be made, and persons tendering must make proposals in their tenders in this respect.

Also, tenders will be received for rails of greater tenacity and of corresponding ductility than the above.

Should the rails not stand the above tests in a satisfactory manner, or if the section, length, etc., are not exact, the railway company may reject the whole delivery.

Weight.—The normal weight of each delivery will be determined by weighing 100 perfect rails.

In general the weight is 34.2 kilos per meter; excess weight will only be paid to the extent of 2 per cent. Rails weighing more than 2 per cent. under normal weight will not be received.

Inspection.—The control of the manufacture, testing, and final reception of the rails will take place at the works. Should, in spite of this reception, any faulty rails be found when coming to be used, these may be rejected.

Delivery.—Delivery to be free on board at Berlin Station. The delivery must be hastened as much as possible, but must be completed at latest three months after adjudication of the quantities.

Penalty.—Penalty for delay: 1 per cent. of the value of the delivery for the first week, 2 per cent. for the second week, and 3 per cent. for each further week. In case of delayed delivery the railway company may also levy against the contractor.

Caution Money.—The contractor must deposit 5 per cent. of the value in bills of exchange, with the understanding that the non-fulfilment of the obligations entered into empowers the railway company to refund itself out of the bills for any loss or damage arising.

Guarantee.—Guarantee ten years. The directors may choose to settle for the defective rails by payment, instead of having them replaced by new ones.

Payment.—Payment takes place after the termination of each delivery through the chief treasury at Berlin.

APPENDIX IX.

LETTERS REFERRING TO DR. DUDLEY'S PAMPHLET.

TRANSLATION OF A LETTER FROM P. RITTER VON TUNNER TO THE AUTHOR.

In your letter of the 26th inst. you ask me which steel rails I consider the most durable, those made from soft or those made from hard steel. The answer is simple: neither the harder nor the softer steels can, in this respect, be considered decisive, the ultimate tensile strength of the material being the property of importance. Since the greatest absolute strength does not coincide with the greatest hardness or the greatest softness, but lies between these extremes, so must the greatest durability of the rail lie there too.

Besides this, it is my opinion that not only the durability of the rail, but pre-eminently the durability of the tires should be taken into consideration, for the tires cost about three times as much as the rail, weight for weight. The harder the rails the more must the tires suffer, on which account I consider hard steel rails entirely inadmissible. . . . . .

LEOBEN, December 4th, 1879.

TRANSLATION OF A LETTER FROM WEBER.

. . . Dr. Dudley's pamphlet is very interesting, but the experiments are made on too limited a scale to be of value. In Germany the battle between iron and steel rails is entirely decided, and I do not believe there is a single railway of importance ordering iron rails to be laid in open tracks. Also the question of hard and soft steel has been decided in favor of the latter. The railway managers cannot get the rails soft enough. The durability of the soft

rails is quite extraordinary, and causes serious anxiety to the steel works. The wear by abrasion is excessively small; the renewal on account of faults is also very small, so that we can estimate the life of soft steel rails with ordinary traffic at twenty to twenty-five years, while the life of good iron rails, under the same conditions, is only eight to ten years.

There are now laid down in Germany more than half a million tons of soft steel rails, which are subject to constant inspection. I am preparing to collect and arrange the results systematically, and as soon as the work is ready I will send it to you. . . . .

November 29th, 1879.

LETTER FROM EDWARD WILLIAMS.

. . . . . I have read carefully the interesting pamphlet on the chemical composition of steel rails that you kindly sent to me.

Dr. Dudley's hypotheses, though ingenious and evidently the result of careful experiments by an able man, will not, I believe, be confirmed by experience in a large way.

My opinion is pretty much that pithily expressed on page 86 of the pamphlet by Mr. Jones, of the Edgar Thomson Steel Works, viz.: "The first thing, in my opinion, toward making a good serviceable steel rail is to make a sound ingot, free from porosity, sponginess, or honeycombs, and as hard as is compatible with safety."

Much harm is being done by chief engineers of railways, who, in their dread of accident from breakage of rails, specify extreme falling tests, to meet which makers must produce rails that are very soft.

To my mind it is clear that the harder a rail is the better for a railway, unless while it is hard it is brittle.

As you very well know iron rails were safe against brittleness, if they bore the shock of a monkey of 6 or 7 cwts. falling 9 or 10 feet, and I have never been able to guess why more than this test should be insisted upon for steel, or indeed any other material suggested for rails.

Let the ingot be as sound as possible, all care taken against overheating (which is a very common source of mischief), and the rails, after rolling carefully, treated so as not to be nicked or otherwise injured in the processes of straightening and finishing, and there will be good steel rails if makers are not forced by the requirements of inspecting engineers to make them needlessly soft.

Such is my opinion for whatever it is worth, and at your convenience I shall be glad to know how it accords with your own and that of others skilled in the matter.

MIDDLESBROUGH, December 10th, 1879.

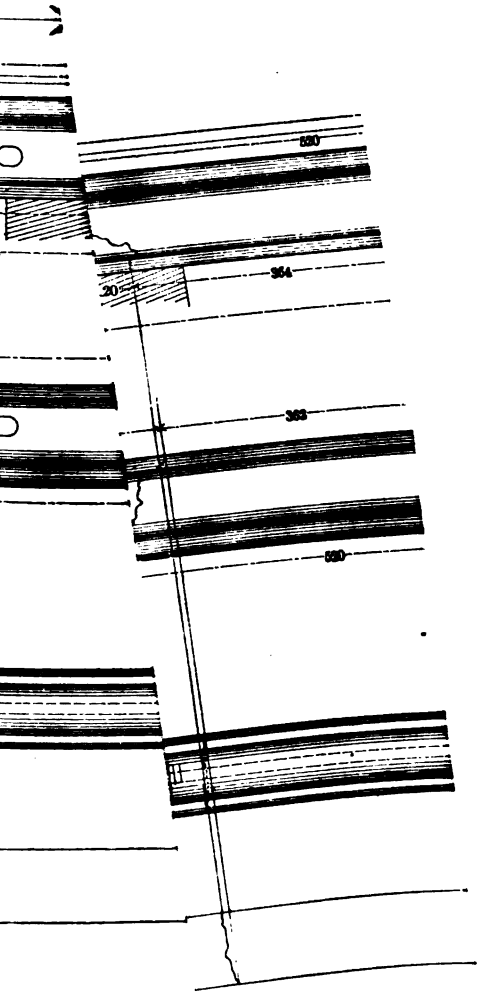
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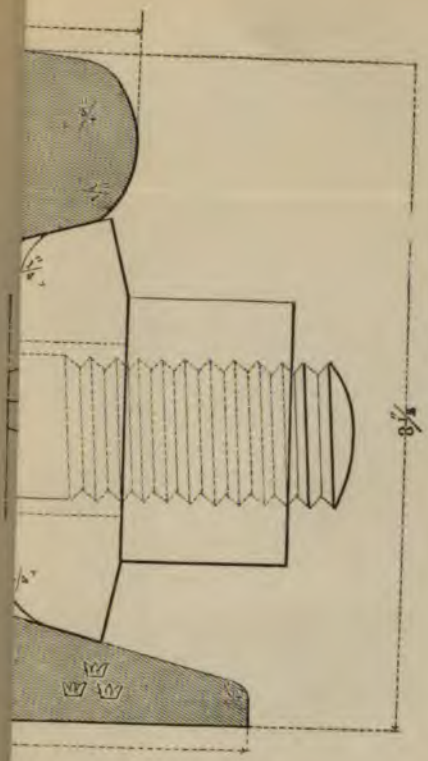
Plate I.



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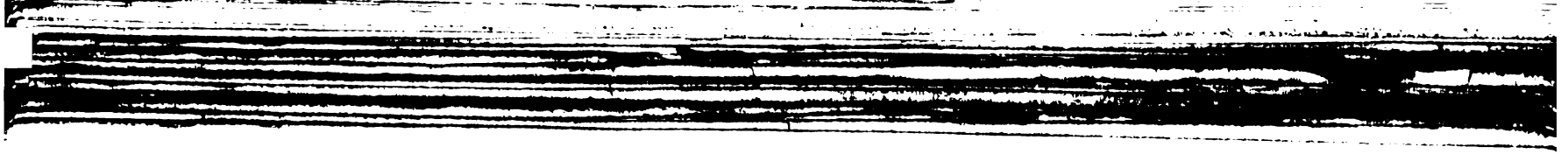


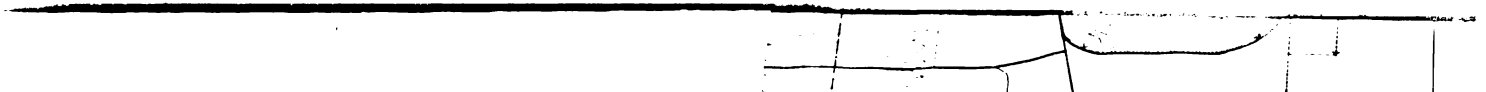
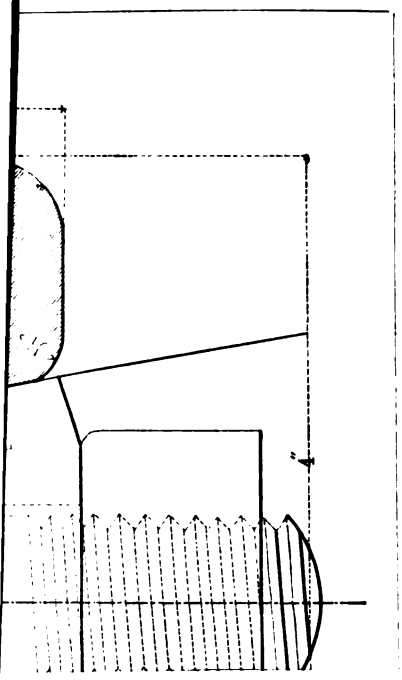
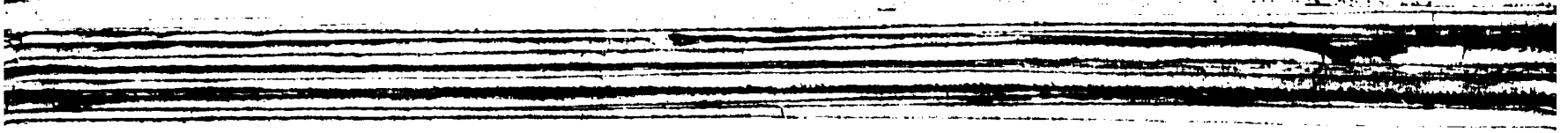


Plate II.





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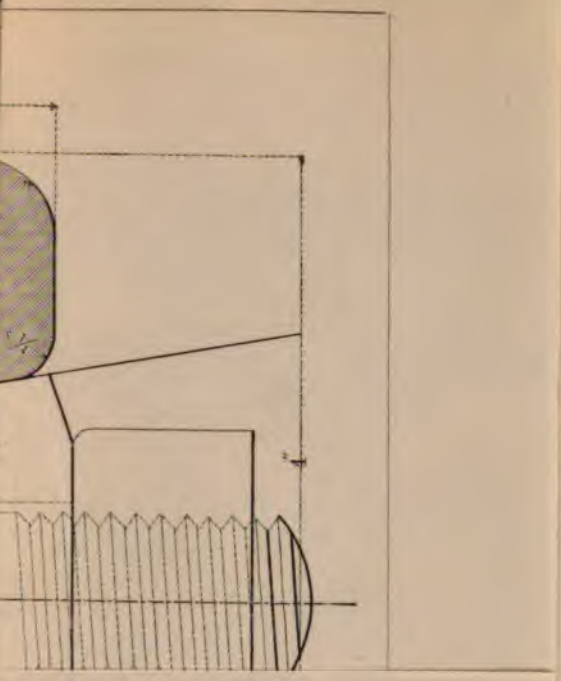


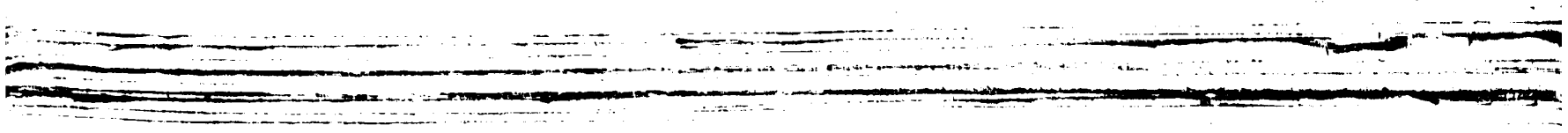
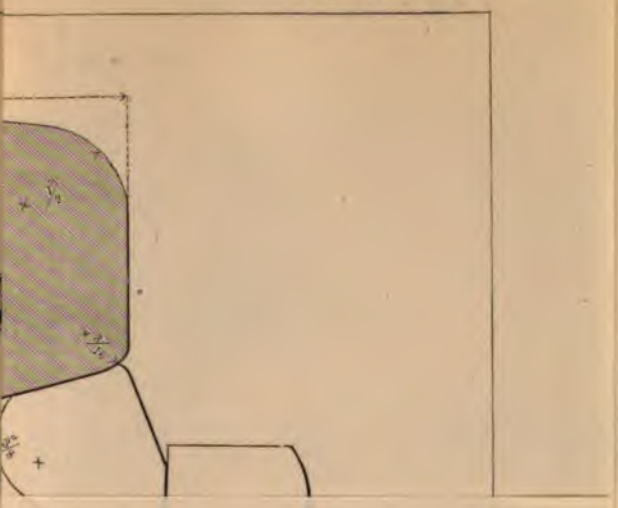


Plate III.



THE WHOPPER LODE, GUNNISON COUNTY, COLORADO.

BY PROFESSOR PERSIFOR FRAZER, PHILADELPHIA.

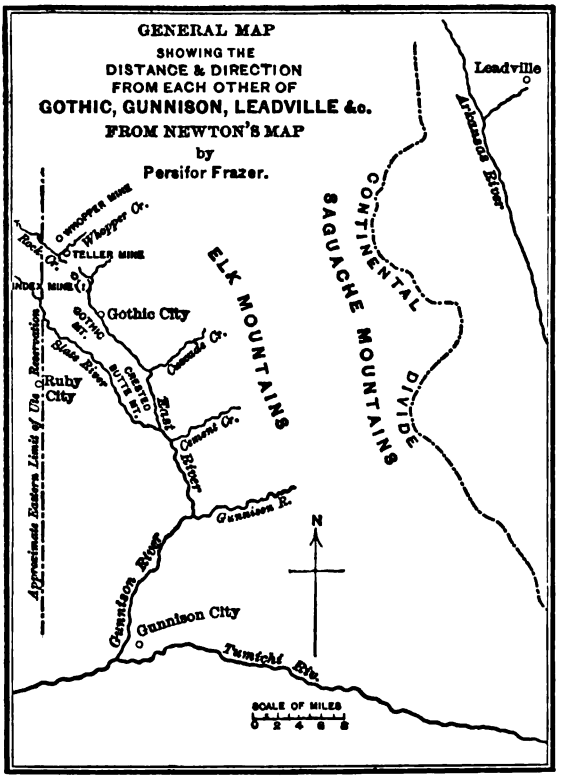
THE following notes on the Whopper and adjoining mines in the unnison district of Colorado were made in the spring of this year. he time chosen for the author to visit the region was, unfortuately, the most unfavorable of an exceptionably unfavorable year. bout the middle of May all the hill slopes, which at this period of he year are generally covered with pasture, were thickly covered ith snow. The unusually large precipitation of this year caused cal mountain torrents at every few hundred feet, which wore away he soft foothills into gulches, gouged great chasms out of the roads, nd transformed miles of usually dry soil into dangerous quagmires. ravel was totally interrupted for weeks, except on horseback or oot, and even then with great difficulty and some danger.

The Whopper mine is situated on the Whopper Mountain, about vo miles from the headwaters of Rock Creek, and on the right ank of that stream. The Whopper Creek flows into Rock Creek om the east, and, by a precipitous descent, offers excellent facilies for its utilization as a source of power. This stream, which ours past the picturesque Whopper Cabin about thirty tons of ater a minute, has a fall of 100 feet in 400 yards, and is said to be stream of some size, even at the seasons of the year when drought revails.

The Whopper claim extends down the hill a distance of about 250 et to its intersection with the Whopper Creek (on the other side which is a small tunnel on its extension called the "Teller") and er the steep hill northwest to the limits of the claim about 1250 et. The part of the mountain in which this mine is situated is markable for its splendid forest, the spruce, fir, and quaking asp overing the mountain-sides with a green growth of valuable timber. he distance from Gothic City to this mine is about eight miles ong the valleys of East River and Rock Creek, and on the divide hich separates them. The elevation of Gothic City is given from he engineer's notes as 9500 feet above sea-level, and the mean several observations with a Beck watch-barometer made the evation of Whopper Cabin (which is about fifteen feet above the oor of the Whopper upper tunnel) about 1250 feet above Skiles's abin in Gothic City. The record of this instrument must, how-

ever, be taken with caution, as its performances were neither consistent nor otherwise satisfactory.

The geographical position of this region will be evident from a glance at the accompanying map, which includes Leadville, Gunnison City, and Gothic City.



There are said to be two coal-fields, situated respectively about four and five miles from the site of a proposed smelter, which will furnish ample and suitable fuel for its use. The first of these is not far over the divide in Washington Gulch; the other is situated down Rock Creek, and is said to be a seven-foot vein of solid coal, well exposed.

A partial analysis of a coal received from Mr. J. W. Skiles, Jr., and said by him to have been taken from the dumps of the coal mines situated at a very short distance from the town of Crested Butte, where the road leads up towards Ruby Camp, was made by me. It is a brilliant coal of low specific gravity, high lustre, and

fair tenacity. It cleaves easily into small fragments, more or less cubical, does not soil the fingers, and burns with a whitish-yellow, luminous flame, like cannel coal.

	Per cent.
Hygroscopic moisture,	0.75
Volatile hydrocarbons,	28.85
Ash (of brownish-cream color),	4.48
Fixed carbon,	64.02
	98.10

Fuel ratio, $\frac{\text{Fixed carbon,}}{\text{Volatile hydrocarbons,}} = 2.22$

This coal belongs, therefore, to the class of bituminous coals, and in fuel ratio resembles that from the Snow-Shoe mine and that from Orangeville, both of Pennsylvania.*

Neither of these coal-fields was, at the time of my visit, open for examination, on account of the unusually heavy snows. In this connection, the record of an analysis of coke made from the Gunnison coal, contained in the *Engineering and Mining Journal* of April 5th, 1879, will be found interesting:

Carbon,	89.00
Hydrogen, nitrogen, and oxygen,	2.50
Ash,	8.50
	100.00

Such coke, if coherent and tenacious, would make an excellent reducing agent in the furnace. The average wages of miners and workmen generally in this region is about $3 per day, but this, it is thought by some of the largest employers, will be reduced during the coming summer. Skilled laborers obtain more, according to the responsibilities of their position and the difficulty of replacing them. Foremen of mines (bosses), engineers, etc., get $5 a day and their board; extra good miners get $4 a day.

The Whopper Lode.—The developments of the Whopper lode consist of an upper tunnel, which is driven in about 66 feet, a lower tunnel, about 21 feet vertically below the upper tunnel and 37 feet in length (about 26 feet of which is timbered through the loose débris and slide on the side of the hill), and two small shafts, about 10 feet deep, situated, one at about 800 feet, and the other about 1170 feet, northwest of the mouth of the upper tunnel. The strike of the lode from the Teller to the upper tunnel of the Whopper is

* See Classifications of Coals, by the author, Transactions of the American Institute of Mining Engineers, vol. vi, p. 430.

about N. 26° W. The course of the vein through the latter is about N. 35° W. The average course of the entire lode from the Teller tunnel to the excavation (to be mentioned presently), within 30 feet of the extremity of the Whopper claim, is N. 33° W., though within this distance there is a variation in the direction of the lode, as shown by the position of the small shaft marked E on the accompanying rough-sketch map, which represents the first of the two small shafts on the lode which was visited. Throughout the Whopper claim the direction of the lode may be taken as N. 33° W.

The lode is a true fissure vein, both walls at the upper tunnel being "quartzite," fine-grained, and compact. Under the microscope this rock proves analogous to the orthofelsite (so called by the writer) found in the South Mountain of Pennsylvania and elsewhere, or the orthophyr, previously described by Dr. T. Sterry Hunt. Its base seems to be a fine mass of orthoclastic feldspar and quartz, intermixed so intimately as to have received the name of jasper by Rogers.

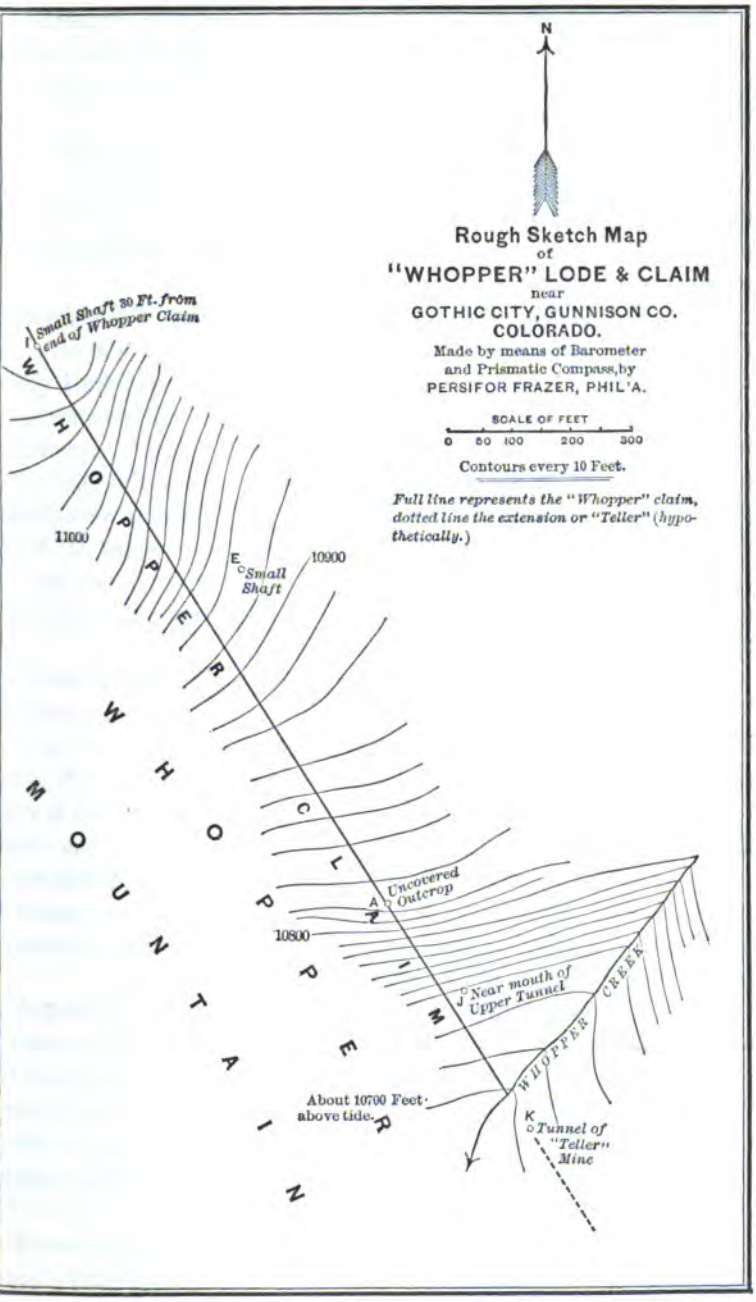
There is a slight difference in quality between the hanging and foot walls, but it is only slight. The face of the rock in which the Whopper crevice shows is exposed to the southeast for about 200 yards. For this distance planes of bedding or cleavage dip about N. 15° E. Another façade of the same rock, which joins this one at a corner, shows planes of similar character dipping north. At the junction of these two slightly unconformable planes the Whopper Creek finds its bed.

At the heading of the upper tunnel the crevice is about 31 inches at its widest part and 19 inches at its narrowest. Taking the average width of the crevice at 26 inches, and estimating the amount of pay-streak from the surface exposed to view, there would be about half pay and half barren quartz. The gangue both here and elsewhere is quartz and the country rock quartzite, but the rich portions of the vein are so irregularly and intimately mixed up with the barren gangue, that only a moderately approximate estimate of the relative amount of each is possible.

The ore is mainly pyritiferous in character. In the quartz gangue small and large crystals and lumps of pyrite and chalcopyrite are visible, together with occasional particles of galena.

A careful selection of ore was made across the breast at the heading of the upper tunnel by picking specimens out of the rock in place across the entire vein. These were dried and pulverized and assayed, showing low grade.

A new section was made across the heading of the upper tunnel after the result of the first assay was known. The precaution was



taken of putting in a shot to clean the face of the decomposed and weathered rock left where the operations last stopped. This gave confirmatory results. A similar section across the breast of the lower tunnel heading was made, and the carefully mixed samples submitted to two assays, which resulted in giving a very high silver content.

It was not thought safe to assume that these results, from the weathered surface of the shallow tunnel, represented the average richness of the vein, since it is well known that the effect of atmospheric decomposition on the surface of an argentiferous vein is often to concentrate the silver.

A small shaft has been sunk within about 30 feet of the extremity of the Whopper claim. In this shaft the appearance was of a vein about 3½ feet in width. The gangue was a blue-veined quartz with a dip of E. 35° N.—75°; just above this, in the same opening, the material seems to dip S. 45° W.—42°. The appearance here is of an anticlinal of gangue, but in no part of the gently dipping limb were any of the minerals discoverable which were plainly seen in the other. A number of fragments were knocked out of this (the hanging wall) without finding any metalliferous matter. A sample from the opening gave on assay a high content of silver per ton.

At another small shaft, situated about 800 feet northwest of the Whopper upper tunnel, and, therefore, not very far from midway between the extremities of the claim, the vein disclosed is smaller than elsewhere observed (not 2 feet), and dips N. 30° E.—70°. Both foot and hanging walls are of the same material, viz., a black trap-like rock having the fracture and general appearance of the rhomboidal slates of the Lower Silurian, and the texture and tenacity of meta-dolerite. This latter was so much crushed that the planes of bedding were indistinguishable. Two assays of an average sample gave a medium-grade ore which would pay well.

The only part of the outcrop which was sufficiently cleared to admit of an examination was a spot about 200 feet northwest of the mouth of the upper tunnel, and 100 feet above it. The dip of the walls was about W. 10° S.—82°. The gangue, which was quartzose and partially decomposed, was about 31 inches wide, of which about half might be reckoned as pay-streak. An average sample of the latter indicated on assay a high-grade ore.

There were three dump-piles at the mine, two near the mouth of the upper tunnel, and the third close to the mouth of the lower

unnel. These were carefully measured and the contents averaged n the following manner: Along one or two imaginary lines over he surface of the dump, and joining the opposite sides of the base, ragments were taken about every 6 inches and laid aside. The ump was then cut vertically from top to bottom and specimens elected in the same manner. All these specimens were thoroughly ixed, divided, and mixed again, and after the third mixture and ivision 20 or 25 pounds were selected for sampling. One of the ump piles near the upper tunnel contained 67 cubic feet, and had n average specific gravity, from experiment, of 2.76, making about .74 tons in the dump. The assay value of the average sample as high. The second dump at the upper tunnel contained about .4 tons, with a low assay value of silver per ton. The third ump at the lower tunnel contained about 58.7 tons, and proved o be a low-grade ore.

The Teller Lode is not a separate lode, but is simply the extension f the Whopper lode to the southeast. Its only development consists of a short assessment tunnel of about 11 feet, separated from he end of the Whopper claim only by the creek of that name. The ountry rock is a quartzite and the gangue is quartz and the ore is ot distinctly separable in the face of the tunnel. The dip of the ode is S. 40° W.—62°. The appearance of the vein is comparaively barren, except for about a foot on the hanging wall and at the eading. The average thickness is about 26 inches. A sample of he pay-streak on the southwest side gave low results in two assays.

The Index Lode is situated in the general direction of the Whopper and Teller lodes, about half a mile in a southeasterly direction. The condition of the country made it impossible to trace the outcrop f the Whopper to the Index, so that the identity of the two lodes s simply a matter of probability.

The only developments of the Index mine are a short tunnel and a hallow shaft, which are close together and situated on the northwest lope of a spur of Galena Mountain. The rock just inside of the mouth f the tunnel shows a vein of quartz dipping E. 30° N.—80°. The rst 15 feet of the tunnel runs about S. 30° E., but alters its course ere and runs S. 20 feet through a large but apparently nearly barren vein of quartz, which seems to intersect the smaller one obquely. The large vein is a white quartz mottled with dark stains, nd dips about southwest, nearly vertical. About 2 feet from the eading is a stratum of soft decomposed rock, *i. e.*, dirt, about 2 feet eep, having the same dip as the vein in which it lies. This white

quartz is not yet cut through. The thickness of the large vein i as above stated, about 20 feet, and that of the small vein about on foot. The country rock is a quartzite so much crushed as to mak the true bedding indeterminable.

The small shaft situated about 20 feet west of the tunnel is abou 10 feet deep and exhibits a vein apparently rich in pyrites, dippin W. 30° N., nearly vertical. In other words, these two veins (th small one and the large one) have strikes respectively of W. 30° N and N. W., and they intersect each other about 70 feet from th mouth of the tunnel. The small vein seems to be rich in metalli erous compounds, and both of them seem to be true fissure veins.

A sample of the soft dirt mentioned above was assayed and gav no silver; a sample of the black stained rock from the walls of th tunnel, about 12 feet from the mouth, was likewise found to conta no silver. Two assays were made of the ore close by the mouth the tunnel, with poor results.

The topography of the country permits the best kind of minin to be prosecuted at a minimum cost. The cost of extracting the o is estimated at about $10 a ton.

With regard to smelting, the ore appears to belong neither to th refractory nor to the *kind* varieties. The cost of reduction, at rough estimate, founded upon the duty of works treating simil ores, would be from $15 to $20 a ton, depending on the suitabili of the process and the skill of the management. As a maximun therefore, the cost per ton in mill run* might be set down at som where near $30.

There is at present no smelter in the immediate vicinity of th Whopper Mine, the nearest being a small 5-ton smelter erected, b not yet completely equipped (July, 1880) in Gothic City; but a distance of one-third of a mile in an air-line (or two-thirds of mile as a wagon road will have to be constructed) from the Whopp and Teller tunnels, is the site of a 30-ton smelter, owned by th Empire Smelting Company, which was purchased and partly tran ported last fall, but which is not yet at its destination. It is e pected to be ready for work in September, 1880. This site is at th northern end of the projected town of Scofield, where, by a flum Crystal Creek is carried to Rock Creek, above the smelter, and th combined waters of the two streams will furnish all necessary pow for blowers, etc. This smelter is intended for the reduction of th

* This expression is used in a loose sense common in Colorado, and means t total product of bullion for a ton of ore mined.

es from the mines owned by the company, and is not a "custom nelter." It can, therefore, only be available for other mines in the cinity, when their ores can be mixed with those from the com-any's mines, or when the latter are deficient in quantity.

There are two mill sites reserved in the new town by the owners, hich will be given to any person or company erecting a 90-ton nelter, or perhaps one of less capacity.

The following is the present schedule of prices paid for ore by iddell & Wetherill at the Harrison Reduction Works, in Lead-lle (April, 1878):

unces of silver, per ton,	50	60	70	80	90	100	125	150	200	250	300	400	500	700	1000
ents per ounce.....	30	40	50	60	61	67	69	74	81	86	89	96	99	103	106

New York valuation of silver $1.20 per ounce. All gold over ½ ounce paid for.

The present schedule of prices paid for ore delivered at the works the Boston & Colorado Smelting Works at Argo, near Denver, based upon a different principle. For ore assaying less than $400 er ton deduct 10 per cent. of the gold at $20 per ounce, 15 per nt. of the silver at market rates in New York, and $20 per ton. or ore assaying $400 to $600 per ton, deduct 9 per cent. of the old, 14 per cent. of the silver and $20 per ton. For ore assaying 600 to $800 per ton deduct 8 per cent. of the gold, 13 per cent. of e silver, and $20 per ton, etc. For the copper contents of any old or silver ores coming under the foregoing schedule, $2 is paid r each per cent., as shown by the dry assay.

On the foregoing basis, ore assaying 5 ounces gold, 10 ounces sil-er, and 2 per cent. copper would be rated as follows:

5 ounces gold at $20,	=	$100 00	
less 10 per cent.,	=	10 00	
			$90 00
10 ounces silver at $1.15,	=	$11 50	
less 15 per cent.,	=	1 72	
			9 78
2 per cent. copper, at $2,	=	. . . .	4 00
			$103 78
Deduct, ...			20 00
Amount paid, ...			$83 78

The most favorable rates of transportation to the nearest market bullion at the present time would be (by way of Gothic City) 5 nts per pound to Alamosa, and thence by railroad rates to Denver. he total cost to the Denver mint would not be over 2 per cent. of e value of the bricks.

The distance of the proposed smelter from Gothic City would be about 7½ miles along the cañons inclosing the streams of East River and Rock Creek, and over the divide which separates their waters. This divide is by the barometer about 575 feet above the Whopper Cabin and about 100 feet more above the smelter site. In spite of the fact that the cañons are narrow and rocky there would be no insuperable obstacle to building a road from Gothic City to the mines and smelters which would probably be passable for nine or ten months in the year; but should the proposed branch of the Denver and Rio Grande Railroad be built from Alamosa through Gunnison to Crested Butte, and perhaps northward to the north fork of the Gunnison River, there will be no need of the proposed wagon-road to Gothic City for purposes of transportation and supply, for the railroad would then pass about four miles from the mines and separated from them by a divide over which a wagon-road could be kept open during all but one or two months in the year.

According to the best information obtainable there are no railways projected into Gothic City. The nearest railway terminus at present which is available for general transportation is Alamosa, about 200 miles distant. The terminus of the Denver and Rio Grande Railroad at Cleora cannot be considered here, because to reach it one must traverse either the Cottonwood or Marshall pass, which have not heretofore been open for freights, except during a short portion of the year.

THE CHEMICAL REACTIONS IN THE BESSEMER PROCESS, THE CHARGE CONTAINING BUT A SMALL PERCENTAGE OF MANGANESE.

BY CHARLES F. KING, NEWPORT, R. I.

THE only investigations on record of the reactions occurring during the Bessemer blow are of charges containing a large percentage of manganese, with the exception of two partial analyses by Snelus and Barker of the English method, where a low percentage of manganese was used. They do not give the analysis of the spiegel, nor do they report any graphitic carbon after the first stage of the process. Both report only traces of manganese after the first stage until the addition of spiegel. The slags corresponding to the samples of metal were not analyzed.

he samples for the following analyses made by me were taken
ne Bethlehem Iron Company's works, Bethlehem, Pa., on No-
ber 13th, 1879. The blow lasted 18 minutes. The converter
12 tuyeres, each with 12 holes of $\frac{3}{8}$ inch diameter. The
ber of revolutions of blowing-engine 2 minutes after start was
er minute with a pressure of $28\frac{1}{2}$ pounds; 12 minutes after start,
er minute, pressure of $23\frac{1}{2}$ pounds; and 15 minutes after start,
er minute.

ight samples of metal were taken, namely, one of the pig charged,
e during the blow, one at the end of the blow, one of the spiegel,
of the final product, and one of the scrap charged before the ad-
n of metal to the converter. Five corresponding samples of
were also taken.

he samples of metal were cast in small ingots, and borings were
n from different parts of these ingots by drilling, great care
g taken that they were not much heated while being drilled.
slags were dumped at once from the small sampling-ladle into
n of water so as to cool rapidly, and they were then dried in an
ath. The sampling was done with care, particles of ganister
shots of metal being separated from the slag.

he elements to which my attention was especially directed,
e graphitic and combined carbon, manganese, and silicon. My
lts are similar to those obtained by others where the charges are
ganiferous.

METAL.

Carbon.—During the first 8 minutes the total carbon dimin-
s only 9.30 per cent. of its original percentage. The carbon in
pig iron on cooling is for the greater part set free by the presence
ilicon as graphite, but after the silicon is oxidized (at the end
he 8 minutes) the carbon remains in the combined form. The
nt loss is due to the fact that carbon has less chemical affinity
oxygen than have silicon and manganese below a certain temper-
e, and above this the affinity of carbon increases rapidly. While,
efore, the silicon and manganese oxidize more readily than
on at temperatures about the melting-point of pig iron, the com-
ion of these elements raises the temperature of the bath until
carbon begins to burn. This characterizes the first period.

t the end of 15 minutes the loss in carbon is 64.783 per cent. of
original percentage of total carbon. In the following 2 minutes
loss becomes 94.168 per cent., and at the end of blow, or 18

minutes, it is 99.04 per cent. of the original amount. After the addition of spiegel the loss is 92.29 per cent. of the total amount of carbon in the charge and in the spiegel.

The second period is distinguished by an elevated temperature, causing the rapid elimination of the carbon by oxidation, the resulting product being chiefly CO with more or less CO_2.

The rate of loss of carbon is greater during the last two-ninths of the second period, or between 15 and 17 minutes, than at any other part of the blow, but small percentages of both graphitic and combined carbon exist in the bath until the end of the process.

According to Kessler, who examined the products of conversions at the Osnabrück works, there was a slight increase in the percentage of carbon, in one case at the end of 4 minutes, and then a slight decrease at the end of 9 minutes, when it differed only slightly from the original amount. From this time on it decreased rapidly. In another experiment the carbon increased slightly to the end of 9 minutes, and then decreased rapidly; the blow lasting 20 minutes in both cases. The only way to account for this gain is in the decrease of the manganese and silicon, which would tend to increase the relative percentage of the other ingredients of the bath.

2. *Silicon* commences to oxidize at the beginning of the blow to SiO_2, and the reaction continues until the end. The loss is 54.60 per cent. of the original amount at the end of 8 minutes, 95.504 per cent. in 15 minutes, 97.61 per cent. in 17 minutes, and 98.33 per cent. in 18 minutes, or the end of the blow. The loss after addition of spiegel is 97.56 per cent. of the total amount of silicon of charge and spiegel. The greatest rate of loss is during the first period, or eight minutes of the blow.

3. *Manganese* is oxidized to the extent of 69.46 per cent. of the original amount present at the end of the first period, or 8 minutes; 72.94 per cent. in 15 minutes, 73.753 per cent. in 17 minutes, and 79.53 per cent. in 18 minutes, or the end of the blow. After the addition of spiegel the loss is 46.904 per cent. of the original percentage, plus the manganese added in the spiegel. The greatest rate of loss of manganese occurs during the first period, or eight minutes. In the accompanying tables and diagrams I give the results of the analyses in convenient form for inspection.

ANALYSES OF METAL.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	Metal charged.	8 minutes after start.	15 minutes after start.	17 minutes after start.	18 minutes after start.	Spiegel.	Final product.	Scrap.	Spiegel reduced to 10.6 p. ct. of charge.
r. { Massive. Pulverized.	6.866 6.818	7.487	6.447 6.200	7.369 7.114	6.706 6.792	7.490	6.691 6.459	7.541	
l carbon...	3.543 3.560	3.199 3.231	1.230 1.270	0.207 0.207	0.034 0.034	4.338 4.396	0.367 0.374	0.264 0.264	0.460 0.460
phite.....	3.16 3.17	0.415 0.438	0.236 0.272	0.0297 0.0273	0.0095 0.0094	0.824 0.827	0.0187 0.0188	0.0149 0.0146	0.087 0.087
bined carb.	0.383 0.390	2.784 2.783	0.995 0.999	0.1775 0.1797	0.025 0.025	3.569 3.514	0.349 0.356	0.2491 0.2497	0.378 0.372
con.....	2.384 2.398	1.07 1.10	0.108 0.107	0.058 0.056	0.037 0.043	0.67 0.68	0.060 0.061	0.103 0.117	0.071 0.072
nganese.....	0.496 0.491	0.151 0.150	0.133 0.134	0.129 0.130	0.097 0.105	16.1290 16.1569	1.175 1.166	1.229 1.212	1.710 1.713
sphorus....	0.089		0.092	0.076			0.0897		

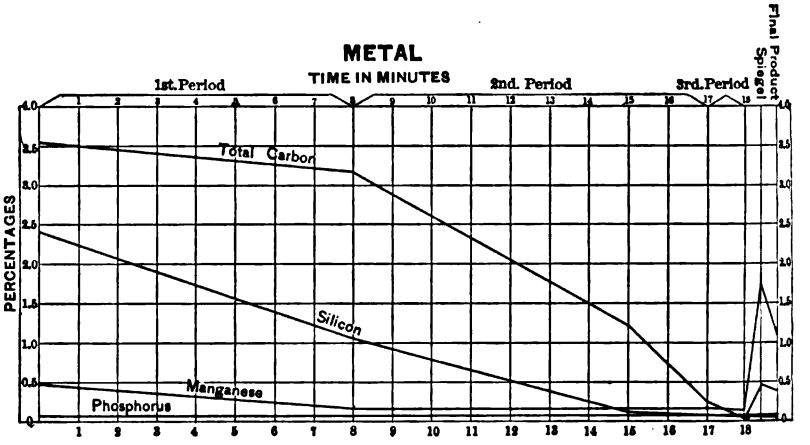
SLAGS.

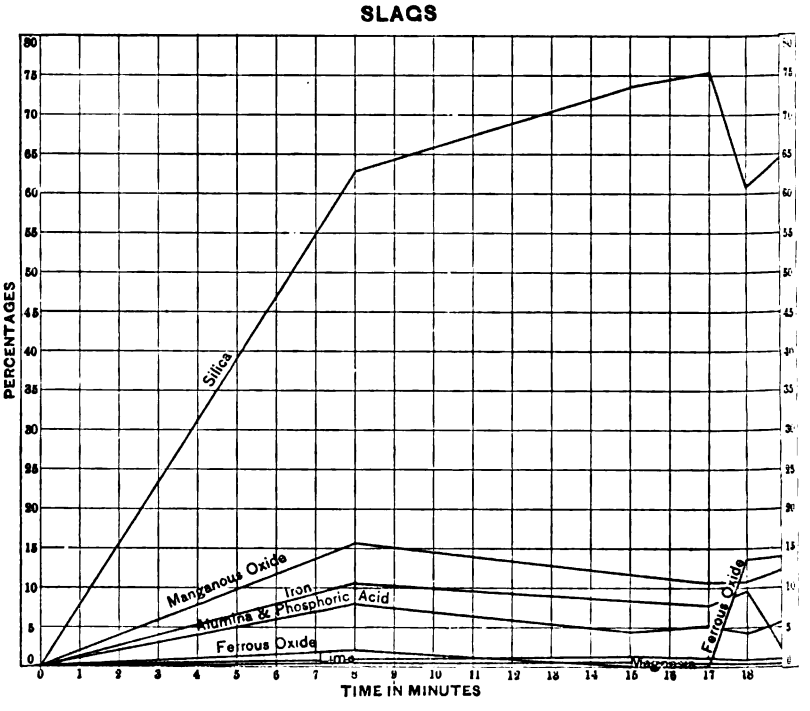
. The silica increased from 62.64 per cent. to 75.63 per cent. n the eighth minute to the end of the seventeenth minute, when uddenly fell to 61.29 per cent., and again increased to 64.15 per t. after the addition of spiegel.

Since we find that the percentage of silicon is also diminished in metal at the same time (from 17 to 18 minutes), this large decrease 4.34 per cent. of silica must be referred to the oxidation of the to FeO, thus decreasing the relative percentage of silica. As will seen from the accompanying diagram, the oxide of iron increases n nothing to 13.5 per cent.

By carefully comparing other analyses I find that the same reacs take place. This period of oxidation of the iron from the sevenenth to the eighteenth minute is termed the third or last period he blow.

. The oxides of manganese and iron decrease regularly in amount n the eighth to the seventeenth minute of the blow, while during next minute the manganese loses only 0.1 per cent., and the iron reases rapidly. Since the manganese in the metal is also dimin-


METAL
TIME IN MINUTES
1st. Period
2nd. Period
3rd. Period
Final Product Spiegel
PERCENTAGES
Total Carbon
Silicon
Manganese
Phosphorus


SLAGS
PERCENTAGES
Silica
Manganous Oxide
Iron
Alumina & Phosphoric Acid
Ferrous Oxide
Lime
Magnesia
Ferrous Oxide
TIME IN MINUTES

ed during this minute the small relative loss shown must be
ing to the increase of the amount of slag. Some of the manga-
se eliminated from the metal may not go into the slag, but be
ried off in the fumes.

The iron exists in the slags both combined as ferrous oxide and
shots of metal mechanically entangled. The amount of shot ex-
cted with a magnet from the sample of slag at the end of 8 min-
es was 33.7 per cent.; from that at the end of 15 minutes, 38.16
r cent.; from that at the end of 17 minutes, 24.37 per cent.;
m that at the end of 18 minutes, 13.8 per cent.; and after addition
spiegel it was 14.20 per cent. of the total weight of slag. The
n, determined by analysis after removal of the shot, calculated
the total weight of slag and shot, was 7.967 per cent. at the end
8 minutes, 5.39 per cent. at the end of 15 minutes, 5.82 per cent.
the end of 17 minutes, 16.89 per cent. at the end of 18 minutes,
d after addition of spiegel it was only 11.36 per cent.

This gives the total percentage of metallic iron in slag, at the end
8 minutes, 41.69 per cent.; at the end of 15 minutes, 43.55 per cent.;
the end of 17 minutes, 30.19 per cent.; at the end of blow, 30.69
r cent.; and after addition of spiegel, 25.56 per cent.

After extracting all iron possible with a magnet from the samples
slag, I found that the sum of the analyses, with all iron calculated
ferrous oxide, was as follows: 103, 102.5, 103, 102.5, and 100.68
r cent. Convincing myself that the analytical work was not at
lt, I then tested the samples with a stronger magnet, and found
ll more metallic iron, and by calculating the iron in Nos. III and
as metallic, and in II, V, and VII both as metallic iron and as
rous oxide, the total of 100 per cent. was obtained for each slag.
e absence of ferrous oxide from slags Nos. III and IV may be
plained by the reducing action exerted by the carbonic oxide
ich is rapidly evolved from the bath of metal during the second
iod.

The variations in amount of the alumina, lime, and magnesia are
ght and of no particular significance, as they come almost ex-
sively from the converter lining.

The results of the analyses of the slags are given below in tabular
m. The diagram on the preceding page exhibits these results in
graphic form in connection with the analyses of the metal.

ANALYSES OF SLAGS.

	II.	III.	IV.	V.	VII.
	8 minutes after start.	15 minutes after start.	17 minutes after start.	18 minutes after start.	After addition of spiegel.
Sp. gr. of powder.....	2.979	2.282	2.411	2.937	2.770
Silica.....	62.656 62.641	73.214 73.260	75.604 75.668	61.293 61.300	64.143 64.165
Alumina and Phosphoric acid.....	7.984 7.985	4.512 4.515	5.203 5.186	4.217 4.267	5.661 5.761
Ferrous oxide.....	1.966 1.890	none	none	13.506 13.446	14.007 13.892
Manganous oxide.....	15.789 15.773	11.839 11.824	10.922 10.921	10.863 10.787	12.813 12.807
Lime.....	0.659 0.653	1.110	0.960	0.747	0.745 0 740
Magnesia.....	0.518	0.641	0.399 0.360	0.288	0.244 0.234
Metallic iron.....	10.502 10.540	8.724 8.712	7.715 7.693	9.086 9.165	2.387 2.401

The conclusions to be drawn from the above analyses are:

1st. Phosphorus is not eliminated where a silicious lining is used, but the proportion is slightly increased, owing to the diminution of weight of the charge of metal.

2d. It is due to the presence of silicon in pig iron that carbon is set free as graphite on cooling, and it is in proportion to the elimination of the silicon that the carbon remains chemically combined. During the first period of the blow the total carbon is diminished very little, but when the temperature rises in the second period, in consequence of the oxidation of the silicon and manganese, the elimination of the carbon is rapid.

3d. Silicon is rapidly oxidized during the first and second periods, at the conclusion of which it is nearly all in the slag.

4th. Manganese decreases rapidly in the metal during the first period, and more gradually during the remainder of the blow.

5th. By the addition of the spiegel the manganese, carbon, and silicon are increased in the metal, and the iron in the slag is decreased.

6th. The final slag carries the silicon and manganese of the charge, l contains 25.56 per cent. of iron.

7th. The first period, or eight minutes, is characterized by a low mperature, during which the silicon and manganese are oxidized; second period of nine minutes, or "boil," is marked by a high mperature, during which the carbon is oxidized rapidly; and the rd period, or last minute of blow, by the rapid oxidation of the n.

APPENDIX.

REMARKS ON INGOTS.

I.

wo castings were taken of I, or pig iron; they were sound; not any drill-holes he one in which the specific gravity was determined. Weight of ingot used for determination of the specific gravity was 1641 grams.

II.

ne casting was taken of II; it chilled and was sound in the part used for spe- gravity determination. Weight of ingot, 430.5 grams.

III.

ne casting was taken of III; it had a few small blow-holes, also three drill-holes en the specific gravity was taken. Weight of ingot, 1354 grams.

IV.

wo castings were taken of IV; they were sound, but had three drill-holes when specific gravity was taken. Weight of ingot, 784.5 grams.

V.

ne casting was taken of V; it was an unsound casting, and had six drill-holes n its specific gravity was taken, which did not seriously interfere with the rmination. Weight of ingot, 945.5 grams.

VI.

ne casting was taken of VI; it had a blow-hole in one end; not any drill-holes. ght of ingot, 745.5 grams.

VII.

ne casting was taken of VII; it had a few small blow-holes and six drill-holes n its specific gravity was taken. Weight of ingot, 1622.5 grams.

VIII.

ive small scraps were taken from bloom-ends, having sixteen small drill-holes n their specific gravity was taken. Weight of scraps, 501.5 grams.

REMARKS ON SLAGS.

II.

ark bluish-brown. It contained a very little ganister, and the shot was mostly ne particles, with a few larger pieces, about the size of a bean. The color of pulverized slag was a dark gray.

III.

Very light yellowish-brown. It contained some ganister in quite small pieces, and the shot mostly in fine particles, with a few of bean-size. The color of the pulverized slag was a very light gray.

IV.

Light yellowish-brown. It contained large pieces of ganister; the shot in fine particles, with a large number of pieces from bean-size down to dust. The pulverized slag was of a light gray color.

V.

Very dark bluish-brown. It contained some ganister in small pieces; the shot in large pieces, also in fine particles. When pulverized the color was very dark iron-gray.

VII.

Light yellowish-brown. It contained some ganister in small pieces, and the shot in large pieces; also, in fine particles. Color of the pulverized slag was a light gray.

NOTE.—The metallic iron was removed with a horseshoe magnet, and the ganister was separated by the aid of a magnifying lens.

CHARGES OF BLAST FURNACES ON NOVEMBER 13TH, 1879.*

Furnaces Nos. 1 *and* 2.

Coal,		2000 lbs.
Ore,	Lehigh Mountain, Pennsylvania. Limonite,	600 "
	African, Bona. Brown Hematite,	600 "
	Crown Point, New York. Magnetite,	450 "
	West End, New Jersey. Magnetite,	300 "
	Irish, North of Ireland. Red Hematite,	150 "
	Elba, Specular,	300 "
Limestone.	Bethlehem Iron Co.'s, at South Bethlehem,	1100 "

No. 4.

Coke.	Connellsville, Pennsylvania,	250 lbs.
Coal,		1750 "
Ore,	Lehigh Mountain, Pennsylvania,	650 "
	African, Bona,	650 "
	Crown Point, New York,	487 "
	West End, New Jersey,	325 "
	Irish,	162 "
	Elba,	325 "
Limestone,		1:00 "

* The above charges are substantially the same as were used at these furnaces at the time the metal was produced, which was blown on November 13th.

No. 5.

Coke.	Connellsville, Pennsylvania,	250 lbs.
Coal,		1750 "
Ore,	Lehigh Mountain, Pennsylvania,	1700 "
	African, Bona,	700 "
	Crown Point, New York,	525 "
	Irish,	175 "
	West End, New Jersey,	350 "
	Elba,	350 "
Limestone,		1200 "

New and Old Northampton Furnaces.

Coke.	Connellsville, Pennsylvania,	250 lbs.
Coal,		1750 "
Ore,	Lehigh Mountain, Pennsylvania,	700 "
	African, Bona,	700 "
	Crown Point, New York,	350 "
	Staten Island,	175 "
	West End, New Jersey,	525 "
	Elba,	175 "
	Marbela, Spain,	175 "
Limestone,		1200 "

No. 7, or Bingen Furnace.

Coal,		2000 lbs.
Ore,	Lehigh Mountain, Pennsylvania,	750 "
	African,	300 "
	Spanish. Brown Hematite,	300 "
	Tilly Foster, New York,	300 "
	Irish, Red Hematite,	150 "
	Elba,	300 "
	Evans, New Jersey,	300 "
Limestone,		1200 "

BLOW "R. A., 876," NOVEMBER 13TH, 1879.

Record of Charges in Cupola.

Bethlehem Furnace, No. 1,		1400 pounds.
" " " 2,		1400 "
" " " 4,		1800 "
" " " 5,		1800 "
Northampton Furnace, New,		1880 "
" " Old,		560 "
Bingen Furnace (No. 7),		3000 "
Robesonia Pig Iron,		2000 "
Maryport "		560 "
Old Moulds,		600 "
	Total,	15,000 "

Record of Charges in Spiegel Melting Furnaces.

Spiegel Furnace, No. 3,	400 pounds.
" " " 6,	150 "
French Spiegel (86 per cent. Manganese),	600 "
German " (11 " "),	550 "
Total,	1700 "
Limestone,	400 pounds.
Coal,	2400 "

Weight of Charges and Products.

Weight of Metal in Ladle,	16,000 pounds.
Scrap (Bloom-ends),	800 "
Spiegel,	2000 "
Ferromanganese,	40 "
Total charge in converter,	18,840 "

Weight of Steel Produced.

Ingots,	16,720 pounds.
Castings,	480 "
Scrap,	300 "
Total,	17,500 "

Loss of metal by conversion, 7.112 per cent.

EFFECT OF SEWAGE ON IRON.

BY CHARLES O. THOMPSON, OF THE WORCESTER (MASS.) FREE INSTITUTE.

In 1867 the city of Worcester walled in the Mill Brook for its main sewer.

This stream, one of the important affluents of the Blackstone River, flows through the city in a southwesterly course from Salisbury Pond, and along its valley a considerable part of the heavy manufactories of the city are placed. At two points, a mile apart, a sufficient fall occurs to be turned to account for motive power, and at many points it was the right and practice of the riparian proprietors, prior to 1867, to use the water for steam and other manufacturing purposes. But the

ltiplication of branch sewers all leading into Mill Brook, soon dered the water unfit for use in contact with heated iron, and the ter privileges were abandoned under equitable arrangements.

A large number of cases involving interesting chemical questions se during the progress of negotiations between the city on the one nd, enforcing its newly acquired sewerage rights, and the proprietors the other, defending their time-honored riparian rights. For in-nce, did the sudden introduction of branch sewers add pollution a stream already foul from riparian stables, pig-styes, etc.? or, if , did this increase in a few months equal that of the natural pol-ion of the stream during the preceding ten years while the city d been doubling its population?

Again, at a point just above the beginning of the dense manufac-ing district, but below the works of the Washburn & Moen Manu-turing Company, the city gas-works discharged the usual waste o Mill Brook, and had done so from the beginning of the gas-pply. If now, the sewage-water, at different points in the valley, s found to act violently upon the iron of boilers or to froth in a rvellous fashion, could a portion of that injurious action be traced the gas-waste or even to the discharge of acid liquors from the ire-works?

Also the cloaca maxima after passing the manufacturing district, erges into an open, walled channel, and runs two miles to Quin-amond village into a mill-pond which, of course, becomes a set-ng-basin. The accumulating filth gradually fills the basin, and es it all the faster by the indirect agency of an enormous growth aquatic plants which thrive on the garbage. These plants gradu-y form islands, and the extinction of the reservoir becomes only a estion of time.

After leaving this mill pond the water still carries a great quan-y of sewage, and at Saundersville generates a novel nuisance. A n flows it over a large area so that the water is very shallow; uatic plants with woody stems grow apace in the summer; the sistent stems are frozen into the ice in early winter, forming a uine horizontal filter for the sewage matter under the ice; and the umulation of solid matter around these multitudinous rigid stakes sufficient to check the flow of the water and thus deprive the nufacturer of the use of his wheel during the winter months.

Before reaching Quinsigamond village the sewage stream passes ggishly around the yard of the Pillar Copperas Company, where peras is made by concentrating the pickling-liquors of the city

shops—mainly of the Wire mill. Of course some vesicles of copperas-water are dismissed into the air, and much ammonia is exhaled from the sewer. When the wind is south the precipitation of iron-oxides upon the roofs and sides of leeward houses goes on rapidly, and those persons who do not like brick-red houses are therefore compelled to gratify their æsthetic propensities by process of law. And all along the open sewer pollution of the atmosphere goes on at such a rate as to impair the public comfort if not to endanger the public health.

From this bench of cases, I have selected those which involve the action of sewage-water on iron as the only ones strictly consonant with the objects of this Institute, and will present them without regard to the order of time.

Mill River drains an area of 7.8 square miles, mostly a farming country, before reaching Salisbury Pond, and, after receiving the contributions of the city sewers, delivers at Quinsigamond Mill-Pond, an average daily flow of 4,000,000 gallons between April and December. The amount discharged into it from branch-sewers, in dry weather, was a daily average of 1,500,000 gallons at the time, 1872–73. The water supply of the city was 3,000,000 gallons a day, so that just half the water received from the service was carried off by the sewers. The average solid contents of a gallon of Mill Brook water before receiving any sewers is 36.29 parts per 100,000; that of the largest branch sewer 61.77; or, in brief, each gallon of water which comes in from the branch sewers contains more than one and a half times the solid matter carried by a gallon of the main sewer. But the total outflow from the side sewers being less than one-half that of the Mill Brook, the actual increase of pollution by the side sewers is very small. Still it is enough to throw the responsibility of damage on the city. This is especially enforced by the consideration that the percentage of organic matter in the contributions of side sewers is twice greater than in the original stream.

The first case involving iron was that of William T. Merryfield *v.* The City of Worcester.* The sewer flows past his works, and the water was used through a spray-head in a condenser. This water was slightly alkaline and contained 12.649 parts of solid matter per 100,000, 5.325 parts of which were volatile. Mr. Merryfield complained that the water corroded his condensers, and that this inju-

* See Mass. Reports, Supreme Court, 110, p. 216.

ıs action of the water had greatly increased since the establishment the sewage system.

To decide this point experimentally, after an extended series of vage determinations in the water at different localities, I took ee samples of water,—one from Salisbury Pond, one from a point ow the discharge from the old gas-works, and one from the flume Mr. Merryfield's building. Three clean, covered iron kettles re-ved 4300 grams of water, and were kept at a temperature of 0° F. (the temperature of the condenser), on a sandbath 12 hours. e iron suspended or dissolved in each sample of water was care-y determined before and after this digestion, and was found to e increased in the first 8.63 grains per gallon ; in the second 8.45 ins per gallon; in the third 15.25 grains per gallon, or nearly ible the first. The suggestion of these experiments is that the nixture of the gas-waste did not increase the corrosive action of water, and that the sewage greatly increased it,—76 per cent.

These experiments were repeated with weighed clean pieces of *bar-*n, immersed in same samples of water, in porcelain vessels; other nditions the same as in first set. The air being excluded from the n, the increase of action in third sample over first was 37 per cent. stilled water, under same conditions, took up 9.62 grains per gal-, or $\frac{3}{5}$ths of the quantity taken by the sewage-water, and $1\frac{1}{8}$th the antity taken by the water of Salisbury Pond. Repeated collateral periments decided the question of corrosion against the sewage-ter, and the double grievance of uncontrollable frothing and cor-ion gave Mr. Merryfield some damages. It was an interesting jecture, prior to these experiments, whether or not the quantity alkaline salts in the sewage-water would protect the iron from rosion beyond the reducing power of the organic matter in which bounds. It appears that this is the fact in Salisbury Pond water, not in the sewage-water.

THE DRIVE-WELLS.

n the valley of Mill River, ten drive-wells have been sunk at erent points with the hope of obtaining water fit for boilers, so as ave the cost of the city water. Water is found at depths vary-between 2′ at the north, to 50′ at the south end of the district ıin which they lie—perhaps one-half a mile long. Analysis of mple at the North End, Warren Thread Company, shows :

		Parts in 100,000.
Total solids,		132.0
Volatile portion,		18.0
Mineral portion:		
Calcium sulphate,	6.9	
Magnesium sulphate,	19.4	
Sodium chloride,	21.5	
Calcium carbonate,	9.2	
Silica,	57.0	
		114.0
		132.0

Sample from the Worcester Felting Company's Mill, half a mile below:

		Parts in 100,000.
Total solids,		92.1
Volatile portion,		21.7
Mineral portion:		
Calcium sulphate,	10.0	
Sodium chloride,	26.1	
Calcium carbonate,	6.3	
Silica,	17.0	
Magnesia and iron,	11.0	
		70.4
		92.1

The water issues at the Worcester Felting Company's Works at a nearly constant temperature of 50° F., and the supply is inexhaustible. There appears to be a subterranean lake roughly parallel with Mill River, with a clay slate bottom, which dips south at an angle of about 30°, and undoubtedly approaches the surface again further south, forming a basin. This water has received the surface sewage of the city since the beginning, and has retained mainly the salt. How soon it will become available brine can be determined by a series of observations, but its action on iron is very interesting.

I found the inner surface of a two-inch supply pipe through which the water is drawn into a tank, completely covered with a hard, smooth porcellanous glaze about $\frac{1}{24}''$ to $\frac{1}{16}''$ thick. But the results of a series of experiments in exposing iron to the action of this drive-well water were perplexing enough though decisive against the expediency of using it in boilers. That is to say, it turns out to be cheaper to pay 25 cents per thousand gallons for city water than to use this for nothing, such is the mischievous behavior of this porcellanous scale. Thus 200 grams of bar-iron exposed to this water lost in Exp. 1, .010 grams, in 12 hours; Exp. 2, .080; Exp. 3, .0456; Exp. 4,

ned .010; Exp. 5, gained .009; Exp. 6, lost .042; Exp. 7, lost 76; Exp. 8, *gained* .010; Exp. 9, *gained* .005; Exp. 10, lost 56; Exp. 11, lost .0516. The pieces of iron were cut from the ne bar. In eight cases a loss, in three a gain—conditions being form throughout. I suppose the gains *may* be attributable to perfect washing and drying of the pieces of iron preparatory to ghing. This initial corrosion of the iron goes to explain the in- arable union of the porcellanous scale which forms in this water h the iron. It seems to be a simple case of the disadvantage of iron cement.

Another case closely connected with this was a boiler 4 feet long, ich was used in a bakery, and presented one or two novel points. was used with 25 pounds of steam. I took a 2″ flue from it. For 3″ from the bottom or up to the customary water-line it was nd; then for 10″ the iron was discolored, pitted, corroded, and akened by actual loss of substance to such an extent as to induce apse of the flue under 25 pounds pressure. All the flues were in stantially the same condition, but the *boiler-shell* was sound oughout. The fuel used was coke.

The water shows at this point,

	Parts in 100,000.
Total solids,	32
Volatile,	8
Salt,	10.19

l a copious deposit of clay. It was obvious, of course, that this ter did not act chemically on the submerged part of the flues nor the boiler-shell. What happened was this: During ebullition a ddy deposit containing salt accumulated, by way of spirting, on surface of the flues and of the boiler-shell just above the water. is deposit dried on and adhered firmly to the iron. It must have umulated rapidly from such water as was used. The flues being ler fire burn out rapidly under this coating, but the shell escapes m, being at a constant temperature due to the heated water.

The last case of interest arose from the desire of the city engineer ake the entire sewage of the main sewer through an iron pipe m a point just below the copperas works to Cambridge Street, ut 1200 feet. The copious discharge of ferruginous water from copperas works introduces a new element into the problem. The age-water turns rapidly black after standing in open or closed ss bottles, in light or darkness—it becomes positively inky. I e never observed this phenomenon in sewage-water from any

point above these works. Bottles of it darken a little to be sure, but do not become black. It seems to be attributable to the reduction of the iron salts in solution by the organic matter of the sewage.

I found by trial that bar-iron lost 0.00012 of its weight when exposed to the action of this water for one week, while cast iron lost an inappreciable amount.

The engineer was relieved of the necessity of laying his iron pipe by a change in the plans of the Committee on Sewers; although I think he might have used cast-iron pipes with good effect.

In all these cases, and in many others, there is good reason to believe that *salt* is the constituent of sewage which is most active in attacking and corroding iron; for in all cases where sewage-water has acted on iron at ordinary summer temperatures, a copious precipitate of ferric hydrate has appeared, which it is difficult to explain on any other ground.

I propose to investigate the action of brine on iron, and report at some subsequent meeting of the Institute.

NOTE ON A DIRECT PROCESS FOR TREATING FINE IRON ORES.

BY W. E. C. EUSTIS, BOSTON, MASS.

1st. THE fine iron ore is mixed with a sufficient proportion of fine coking coal, and is coked in any of the ordinary methods for making coke. The effect of this is to convert the iron oxide into sponge in such a shape that the usual trouble of oxidation is avoided.

2d. The resulting mixture of coke and sponge is melted down in an ordinary cupola, the coke furnishing more than sufficient fuel for that purpose.

I may briefly point out here that in the first place the iron is sponged, and this sponge, as is well known, contains no phosphorus or silicon when the reduction takes place at a low temperature; and in the second place this sponge is melted down in a cupola in which there is no zone of reduction for phosphorus or silicon, and that consequently the resulting iron should be free from both of these impurities.

3d. The liquid sponge, now carburized, is run into an open-hearth furnace, where the requisite degree of hardness or softness is obtained by adding some of the fine ore, and the usual dose of ferromanganese.

I have merely given above the rough outlines of the process, but it is my intention, as early as possible, to bring the process more fully before the Institute.

PROCEEDINGS

OF THE

NUAL MEETING IN PHILADELPHIA.

FEBRUARY, 1881.

LOCAL COMMITTEE OF ARRANGEMENTS.

Chairman: WILLIAM LORENZ.
Secretary: JOHN BIRKINBINE.

Finance.—T D. Rand, William Burnham, Israel W. Morris, Henry S. Drinker, T. Townsend, William Sellers, W. A. Ingham, J. A. Wilson, W. G. Neilson, W. Hoffman, E. Borda.

Entertainments.—Persifor Frazer, Franklin B. Gowen, J. P. Lesley, Henry tit, John Birkinbine, Henry S. Drinker, P. Roberts, Jr., R. W. Davenport, lliam Burnham, J. S. Alexander, Charles A. Brinley, G. A. Koenig, William renz.

Hotel Accommodations.—Charles A. Ashburner, C. H. Roney, R. H. Saunders, R. Waite.

Railroad Fares and Excursions.—Percival Roberts, Jr., William Lorenz, ael W. Morris.

Citizens' Reception Committee.—John Welsh, A. J. Drexel, Thomas A. Scott, orge W. Childs, Dr. S. Weir Mitchell, Fairman Rogers.

THE opening session of the annual meeting was held in the hall the Franklin Institute on Tuesday evening, February 15th. ofessor Persifor Frazer, of the Local Committee of Arrangements, roduced the Honorable Wayne MacVeagh, who spoke as follows:

As many of you are probably aware, it was the expectation and purpose of the committee having in charge the reception of the mbers of the Institute in Philadelphia that you should be welned here by our first citizen, whose approved worth and civic tue endear him to us all,—Mr. John Welsh. In his absence it is y necessary for me to say a very few and informal words to assure u that we recognize the honor the members of the Institute do to iladelphia in selecting it as the place for this annual meeting, and tell you that as Philadelphians and as Pennsylvanians we have only been naturally interested, but we have watched the proceedgs of the Institute itself, and the advancement in usefulness and renown of many of its members, whose names are familiar to us household words.

We all recognize, whatever our several duties in life may be, that s age belongs especially to you. It has not been so in the past,

and it may not be so in the future, but these are the days when it is literally true that

> ". . . Science reaches forth her arms
> To feel from world to world, and charms
> Her secret from the latest moon."

This is emphatically the age of scientific inquiry and of scientific development; and in this, the greatest of manufacturing cities, and in this, perhaps, the most important of States, it is eminently fitting that your Institute should assemble, and should be—as it is sure to be—heartily and cordially welcome. We are proud of our resources in Pennsylvania, and we are glad that you bring to them the trained intelligence and energy to make them really fruitful and really valuable. We know that upon you we depend not only that our mineral treasures shall be developed, but that they shall be brought economically to market; that they shall be economically distributed wherever they are needed, and that all the engineering labor needed properly to distribute them, properly to develop them, we will owe to your ability in the line of your chosen profession; and we know that in the year immediately before us the opportunity for your labors to be advantageous to you and to us are likely to be greater than ever before. For it seems to all thoughtful persons as if in the near future a material prosperity greater than has ever heretofore been known awaits America. These are, therefore, days of very happy augury for all the citizens of our common country, for the magnificent possibilities of the nation are now, for the first time, being even dimly understood. To what extent the mere material wealth of a country may be multiplied in the lifetime of the younger members of this Institute is beyond any man's capacity to prophesy, but that we are to continue to be prosperous, and more prosperous with each advancing year, seems to be as well assured as anything in human affairs.

After all, however, you are not only engineers, but citizens, and men as well. And whether this great material prosperity shall, in its influences, be productive of good or evil, depends not at all upon the prosperity itself, but wholly upon the spirit in which we and our children shall accept it. The natural tendency of wealth is, perhaps, not toward refinement, but rather toward vulgarity; not toward elevation so much possibly as degradation of life; and, therefore, none of us should ever forget that the chief blessings which the year can bring us are not after all new mines of gold, or

ver, or coal, or iron, new railways of illimitable length, new wheat-
ds of illimitable breadth,—not even new engineering works of
exampled grandeur and magnitude and utility—not even towns
l cities where forests were,—but that generous culture of mind
l heart which shall give us sweeter manners, purer laws, and
ke us wiser, wider, better men than ever before.

If in this spirit we accept the great advantages which seem to be
thin our reach, we shall prove ourselves eminently worthy of
m. And then, in the procession of the ages, we shall be not
y an indissoluble and mighty and prosperous nation, but we shall
what is far better, a Christian, cultivated people, enjoying the
ine benediction of peace in all our borders, and contentment and
inement in all our homes.

And it only remains for me now to discharge the agreeable duty
expressing to you the good wishes of this entire community, and
the name not only of the Committee of Reception, but of all the
izens they represent, to bid you a hearty and cordial welcome to
iladelphia.

The President of the Institute, Mr. William P. Shinn, replied to
e welcome to the Institute, expressed in the address of Mr. Mac-
eagh, and spoke warmly of the interest which Philadelphians
l always shown in the work and progress of the Institute. The
esident then opened the formal proceedings of the meeting by
ding an address on "The Advance in Mining and Metallurgical
t, Science, and Industry since 1875."

At the conclusion of this address the following persons, proposed
r members and associates of the Institute and recommended by
e Council, were unanimously elected.*

MEMBERS.

Frederick J. Anspach,	Philadelphia.
Charles T. Arnberg,	Troy, N. Y.
William Atkins,	Pottsville, Pa.
Oliver W. Barnes,	New York City.
J G. Benton,	Titusville, Pa.
Walter G. Berg,	Richmond, Va.
William F. Biddle,	Philadelphia.
George D. Bolton,	Calumet, Mich.
Henry N. Brinsmade,	Lake Mahopac, N. Y.
Charles O. Brown,	Tunja, E. E. U. U. de Columbia.

* In the following list are included those elected at subsequent sessions of this
eting.

Horace Brock,	Lebanon, Pa.
Harry H. Campbell,	Steelton, Dauphin Co., Pa.
S. H. Chauvenet,	Harrisburg, Pa.
William Clark,	Pittsburgh, Pa.
F. G. Clemens,	Lost Creek, Schuylkill Co., Pa.
John H. Clemes,	Alamos, Sonora, Mexico.
C. B. Cohen,	Salt Lake City, Utah.
George S. Comstock,	Mechanicsburg, Cumb'd Co., Pa.
Henry P. Cooper,	Parryville, Carbon Co., Pa.
E. D. Cope,	Philadelphia.
W. W. Culbertson,	Ashland, Ky.
E. W. Cramer,	Montezuma, Colorado.
F. P. Davis,	Washington, D. C.
John C. Dods,	Philadelphia.
William Eastwick,	Philadelphia.
Luther G. Emerson,	Hancock, Mich.
A. T. Enos,	Brooklyn, N. Y.
Edgar C. Felton,	Steelton, Dauphin Co., Pa.
S. M. Felton,	Philadelphia.
A. E. Foote,	Philadelphia.
A. E. Frost,	Pittsburgh, Pa.
William Garrett,	Cleveland, Ohio.
I. W. Geary,	Pottsville, Pa.
Austin G. Gorham,	New York City.
Thomas H. Graham,	Candela, Coahuila, Mexico.
John H. Hammond,	San Francisco, Cal.
F. V. Hayden,	Philadelphia.
E. C. Hegeler,	Lasalle, Ill.
L. M. Hooper,	New York City.
E. C. Jewett,	Leadville, Colorado.
T. Catesby Jones,	Lynchburg, Va.
Washington Jones,	Philadelphia.
John S. Kennedy,	Rocky Mount, Franklin Co., Va.
Charles Knap,	Washington, D. C.
Charles Knap, Jr.,	Richardsville, Culpeper Co., Va.,
Joseph M. Knap,	New York City.
C. O. Lagerfelt,	Riegelsville, Pa.
N. M. Langdon,	Chester, Morris Co., N. J.
William A. Leavitt,	Philadelphia.
David B. Lewis,	Marinette, Wis.
Gustav Lincke,	Troy, N Y.
Orleans Longacre,	Lynchburg, Va.
William Lorenz, Jr.,	Philadelphia.
Edward H. Lynde,	Scranton, Pa.
John H. Mars,	Albany, N. Y.
William F. Mattes,	Scranton, Pa.
Spencer Meade,	Harrisburg, Pa.
Lycurgus B. Moore,	New York City.
William H. Morris,	Pottstown, Pa.
O. A. Moses,	Menlo Park, N. J.
Jules Naville,	San Miguel, Ouray Co., Col.

Samuel Noble,	Anniston, Ala.
George Ormrod,	Emaus, Lehigh Co., Pa.
William G. Park,	Pittsburgh, Pa.
Robert E. Pettit,	Altoona, Pa.
Frank E. Platt,	Scranton, Pa.
A. Pluemer,	Cincinnati, Ohio.
S. M. Prevost,	Harrisburg, Pa.
Charles E. Pugh,	Altoona, Pa.
Frank Rahm,	Pittsburgh, Pa.
Joseph W. Revere,	Boston, Mass.
T. B. Riter,	Pittsburgh, Pa.
Henry Roberts,	Johnstown, Pa.
Percival Roberts,	Philadelphia.
W. F. Robertson,	Bergenpoint, N. J.
Ferd. Ruttmann,	Brewster's Stat'n, Putnam Co., N.Y.
C. P. Sandberg,	London, England.
W. S. Schuyler,	Nevada City, Cal.
John Scully, Jr.,	Pittsburgh, Pa.
Henry C. Shaw,	Troy, N. Y.
W. Lesley Sheafer,	Pottsville, Pa.
T. E. Sickles,	New York City.
R. H. Soule,	Baltimore, Md.
Henry S. Sterling,	New York City.
Lewis Stockett,	Ashland, Schuylkill Co., Pa.
N. Allen Stockton,	Philadelphia.
William M. Stone,	Knoxville, Iowa.
Alexander Thomas,	Boston, Mass.
Sidney G. Thomas,	London, England.
Samuel W. Thomé,	Philadelphia.
John L. Thomson,	Capelton, Quebec, Canada.
H. G. Torrey,	New York City.
Leslie Warner,	Chattanooga, Tenn.
George H. Warren, Jr.,	New York City.
H. L. Waterman,	Philadelphia.
David Watts,	Harrisburg, Pa.
William D. Wheeler,	Helena, Montana.
L. E. Wills,	Weissport, Carbon Co., Pa.
Newton R. Wilson,	Leadville, Colorado.
J. Whitaker Wright,	Philadelphia.

ASSOCIATES.

J. Trowbridge Bailey,	Philadelphia.
George T. Carter,	Pittsburgh, Pa.
C. W. Davenport,	Easton, Pa.
W. H. Emanuel,	Easton, Pa.
John H. Irwin,	Morton, Delaware Co., Pa.
Hermann A. Keller,	Philadelphia.
John Meigs,	Pottstown, Pa.
Joseph H. Outhwaite,	Cleveland, Ohio.
Clarence A. Rundall,	Ferrol, Va.

William A. Shepard,	New York City.
Hermann T. Vulté,	New York City.
N. B. Walker,	New York City.
Henry C. Wilson,	Memphis, Tenn.

The status of the following associates was, on recommendation of the Council, changed to member.

F. E. Bachman,	N. W. Lord,
A. D. Churchill,	G. F. Milliken,
W. O. Comstock,	Frank Nicholson,
W. A. Fellows,	R. A. Shillingford,
J. P. Fillebrown,	William Strieby,

H. C. Foote.

Communications were then read from Messrs. Whitney & Sons, the Baldwin Locomotive Works, and the Machine Tool Works, inviting members to visit their respective works; also, an invitation from the Philadelphia *Press* to witness their Bullock press in operation. Letters were also read from the Pennsylvania Museum and School of Industrial Art, the Academy of Natural Sciences, and the Franklin Institute, extending courtesies to the members during the meeting of the Institute.

The President appointed Messrs. Roney, Chance, and Harden scrutineers to examine the ballots for officers of the Institute, and report at a subsequent session.

The exercises of this session concluded with the reading of a paper by Mr. Otto A. Moses, of Menlo Park, N. J., on the Applicability of Edison's System of Electric Lighting to Mines, which was accompanied with an exhibition of mine lamps in incandescence.

After the adjournment of this session the members enjoyed the hospitality of Professor Frazer, at the Penn Club, and had the pleasure of meeting many of the prominent citizens of Philadelphia.

On Wednesday morning, in accordance with the programme arranged by the local committee, the members left by special train on the Philadelphia and Reading Railroad at 9 A.M., and visited, first, the Pencoyd Iron Works of Messrs. A. & P. Roberts & Co., where every facility was afforded for a thorough inspection of the works. The Midvale Steel Works at Nicetown were next visited, under the guidance of the superintendent, Mr. Charles A. Brinley, and his assistants. Returning by train to Germantown Junction, the party was transferred to a special train on the Pennsylvania Railroad and taken to Downingtown, to see the improvements there in progress by the railroad company. At Malvern a considerable number of

members availed themselves of the opportunity to visit Mr. J. op's platinum works, and were there shown the process of melting num by means of the oxyhydrogen blowpipe. Returning to adelphia, the members of the Institute had the honor of being first party carried over the new elevated railroad leading to the terminus at Fifteenth and Market streets. The Public Build-, in process of erection at Broad and Market streets, were then ed, under the courteous guidance of Mr. Samuel C. Perkins, rman of the Public Buildings Commission, and Mr. John Arthur, architect.

he second session was held in the hall of the American Philo-ical Society on Wednesday afternoon, at 4 o'clock, when the wing papers were read:

he Construction of Geological Cross Sections, by H. Martyn nce, of Philadelphia.

New Method of Mapping the Anthracite Coal-fields of Penn-ania, by Charles A. Ashburner, of Philadelphia.

he Use of Salt-coating in the Manufacture of Iron and Steel e, by Charles H. Morgan, of Worcester, Mass.

he Action of Common Salt and other Related Crystalline Salts Wire-drawing, by Professor Charles O. Thompson, of Worcester, s.

he Amount of Manganese Required to Remove the Oxygen from after it has been Blown in a Bessemer Converter, and a Method he Estimation of Manganese in Spiegels, Irons, and Steels, by . Ford, of Pittsburgh, Pa.

n Wednesday evening there was a musical reception tendered he resident to the visiting members and ladies accompanying n at the Academy of the Fine Arts. The Committee on Enter-ments and their wives were assisted by the Citizens' Reception mittee and their wives in receiving the guests of the evening, a large number of ladies and gentlemen of Philadelphia who been invited to meet them.

he third session, on Thursday morning, was devoted to the sub-of steel rails. Dr. C. B. Dudley read an abstract of his paper ich had been previously printed and distributed to members) he Wearing Capacity of Steel Rails in Relation to their Chemi-Composition and Physical Properties, and was followed by Dr. L. Holley, who read a paper on Rail Patterns. The President announced that these papers were open for discussion in con-ion with Mr. C. P. Sandberg's paper, read at the Lake Superior ting, on Rail Specifications and Rail Inspection in Europe.

The following persons participated in the discussion:

Messrs. Ashbel Welch, of Lambertville, N. J., R. W. Hunt, of Troy, N. Y., William Sellers, of Philadelphia, William R. Jones, of Pittsburgh, Pa., and William Metcalf, of Pittsburgh, Pa.

The time having arrived for the adjournment of the session, it was voted to continue the discussion at the session on Friday morning.

The fourth session was held on Thursday afternoon, when the following papers were read:

Notes on the Assay Spitzlutte for Laboratory Use, by Professor R. H. Richards, of Boston, Mass.

Gas Producers Using Blast, by Frederick H. Daniels, of Worcester, Mass. Read by the Secretary.

Coal Washing, by S. Stutz, of Pittsburgh, Pa. Read by Mr. J. D. Weeks.

Shocks on Railway Bridges, and Steel for Bridges, by J. W. Cloud, of Altoona, Pa.

The Origin of Gold Nuggets and Placer Deposits, by Professor T. Egleston, of New York.

There was a subscription dinner of the members of the Institute and ladies and invited guests held on Thursday evening in the banquet-hall of the Union League, which had kindly been placed at the disposal of the Institute by the House Committee of the League.

At the fifth session, on Friday morning, the discussion of the subject of steel rails was resumed. The Secretary read a letter from Mr. W. R. Hart, of Naylor & Co., with reference to a section for steel rails which had been designed by Mr. Ashbel Welsh in 1866. Mr. William Metcalf read a paper entitled, Can the Magnetism of Iron and Steel be used to Determine their Physical Properties? A communication from Mr. George Webb, of the Cambria Iron Company, Johnstown, Pa., was read by the Secretary, and followed by remarks of the President, Mr. Shinn. Mr. William Kent, of Pittsburgh, Pa., read a paper analyzing Dr. Dudley's results. The Secretary read communications from Dr. August Wendel, of Troy, N. Y., from Mr. F. G. Field, of London, England, and from Mr. R. H. Sayre, superintendent and engineer of the Lehigh Valley Railroad, Bethlehem, Pa. The discussion was then continued by Professor Egleston, of New York, and Messrs. J. W. Cloud, of Altoona, Pa., Jacob Reese, of Pittsburgh, Pa., Otto A. Moses, of Menlo Park, N. J., G. A. Koenig, of the University of Pennsyl-

, Philadelphia, S. A. Ford, of Pittsburgh, Pa., C. E. Stafford, eelton, Pa., and was concluded by Dr. Dudley. Mr. W. R. then moved a vote of thanks to Dr. Dudley for his valuable ibution to the knowledge of the subject of steel rails. The n was seconded by Mr. R. W. Hunt, and was carried unani-ly.

e sixth and closing session was held on Friday afternoon, when llowing papers were read:

e Whitwell Stove and its Recent Improvements, by Fred. W. on, of Pittsburgh, Pa.

rnishing and Ductilizing Steel, by Jacob Reese, of Pittsburgh,

e Brazos (Texas) Coal-field, by Charles A. Ashburner, of Phila-ia.

e Occurrence of a Lustrous Coal in a Fissure Vein Associated Native Silver, Gold, and other Minerals at the Dexter Mine, ado, and A New Silver Bismuthite from the Alaska Mine, ado, by Professor George A. Koenig, of the University of sylvania, Philadelphia.

e Industrial School for Miners and Mechanics at Drifton, Pa., swald J. Heinrich, Drifton, Luzerne County, Pennsylvania.

e Secretary read a communication from Mr. Theodore E. arz, of Georgetown, Colorado, accompanying a gold crystal h had been found in a mercury-tank at the Empire Mill, Colo-

e report of the scrutineers was read, announcing that the fol-g persons had been elected officers of the Institute.

PRESIDENT,

WILLIAM METCALF, ...	Pittsburgh, Pa.

VICE-PRESIDENTS,
(To serve till February, 1883.)

J. P. KIMBALL, ...	Bethlehem, Pa.
W. H. PETTEE, ...	Ann Arbor, Mich.
C. O. THOMPSON, ...	Worcester, Mass.

MANAGERS,
(To serve till February, 1884.)

J. S. ALEXANDER, ...	Philadelphia.
H. S. MUNROE, ...	New York.
J. C. F. RANDOLPH, ...	New York.

TREASURER,

THEODORE D. RAND, ...	Philadelphia.

SECRETARY,

THOMAS M. DROWN, ...	Easton, Pa.

A change of the rules, which had been announced at the previous meeting, namely, to omit from Rule VI the final paragraph with reference to notices, was then voted.

The Secretary read the following report of the Council:

The Council of the Institute, in accordance with the Rules, makes the following report of the condition of the Institute and its work for the past year:

Two meetings only were held,—the annual meeting in New York in February, 1880, and the fall meeting in August on Lake Superior. The latter meeting was largely attended, and must be regarded as one of the most enjoyable and profitable meetings we have ever held. The extent of mining territory visited, and the pleasant accessories of the excursions on the lake, combined with the abundant hospitality of the resident engineers, render this meeting memorable in the history of the Institute. Owing to the length of time required for this excursion, it was thought best to consolidate the spring and fall meetings.

At both meetings there were a large number of papers presented which have mostly been printed and distributed to members. At the Lake Superior meeting Mr. C. P. Sandberg's paper on "Rail Specifications and Rail Inspection in Europe" brought the important subject of steel rails again before the Institute, which paper, in connection with Dr. Dudley's paper on the "Wearing Capacity of Steel Rails," to be presented at this meeting, will provide abundant material for discussion.

Vol. VIII, *Transactions*, has been issued, and has been distributed as usual.

There were elected at the two meetings 114 members and 24 associates. There have been dropped from the roll, after due notification, for non-payment of dues, 55 members and associates, and 9 have resigned. Seven members have died: W. B. Caldwell, Jr., H. M. McIntire, J. W. Mickley, Henry Pleasants, Thomas W. Robinson, I. M. St. John, and Henry R. Worthington.

The membership now comprises 6 honorary members, 52 foreign members, 680 members, and 105 associates,—in all 843.

The employment agency of the Institute has done good work. There have been 40 applications from employers, and 36 applications from those wishing positions. A considerable number of the applications have been successfully provided for, and the value of the agency established.

e accounts of the Secretary and Treasurer, duly audited, ex- a most satisfactory state of the finances of the Institute; they s follows:

RETARY'S AND TREASURER'S STATEMENT OF RECEIPTS AND DISBURSEMENTS, FROM FEBRUARY 1ST, 1880, TO JANUARY 31ST, 1881.

DR.

ce at last statement,	$634 21	
ved for dues from members and associates,	6956 00	
" life memberships,	200 00	
from sale of publications,	290 50	
author's pamphlets,	151 75	
for binding *Transactions*,	180 58	
" electrotyping,	22 00	
st,	70 65	
		$8505 69

CR.

or printing vol. viii., *Transactions*,	$1515 48	
binding " "	368 00	
printing pamphlet editions of papers,	1216 75	
printing circulars,	110 25	
binding *Transactions*,	31 50	
engraving,	863 00	
lithographing,	200 00	
stationery,	47 35	
postage,	557 15	
telegrams,	20 62	
freight and express,	100 25	
insurance,	47 50	
binding exchanges,	76 25	
Secretary's salary,	2000 00	
" expenses at meetings,	241 99	
electrotyping,	55 40	
		$7451 49
s of receipts over expenditures,		1054 20
t for dues received in advance,		210 00
us for the year ending January 31st, 1881,		$844 20

his surplus will enable us to fund the life memberships, which not hitherto been possible.

r. J. S. Alexander, in charge of the exchange of the collections the German Government, reports that satisfactory progress is made. One of the desired collections, composed of the Clai- e shells, contributed by Professor E. A. Smith and Professor . Mell, Jr., of Alabama, has been forwarded, its receipt ac- vledged, and a return collection received, together with colored s showing the production, consumption, and circulation of mal-

leable iron products, and also of cast iron in Prussia during the year 1878.

The following papers were then read by title by the Secretary:

Note on the Estimation of Copper in Speise, by F. C. Blake, Mansfield Valley, Pa.

In North Carolina Corundrum unmistakably occurs in Igneous Rocks, and Auriferous Slate Deposits of the Southern Mining Region, by Professor P. H. Mell, Jr., of Auburn, Alabama.

The Carbonic-acid Gas Process at the Kehley Run Colliery, by H. Martyn Chance, of Philadelphia.

A Summer School of Practical Mining, and Ore-dressing in Missouri and Colorado, by Professor H. S. Munroe, of New York.

The Gold-bearing Mispickel Veins of Marmora, Ontario, Canada, by R. P. Rothwell, of New York.

Ore Dressing and Smelting at Pribram, Bohemia, by Ellis Clark, Jr., of Philadelphia.

Analyses of Coals from Gunnison, Colorado, by Professor P. Frazer, of Philadelphia.

A New Bottom for Bessemer Converters, by C. F. Manness, of Scranton, Pa.

Use of Coke in Anthracite Furnaces, and a Modern Charcoal Furnace, by J. P. Witherow, of Pittsburgh, Pa.

Supplement II to a Catalogue of Official Reports upon Geological Surveys of the United States and Territories and of British North America, by F. Prime, Jr., of Baltimore, Md.

Naval Armament, by C. R. Boyd, of Wytheville, Va.

The Condition of Sulphur in Coal and its Relation to Coking, by Thomas M. Drown, of Easton, Pa.

Memoranda on the Analysis of Statistics, by A. W. Hale, of New York.

Ore Roasting Furnace, and a Fluxing Gas Producer for making Heating Gas, by W. J. Taylor, of Chester, N. J.

The following resolution was offered and carried unanimously:

Resolved, That the Institute desires to express its feeling of deep gratitude towards the many gentlemen and corporations who have, by their exertions and friendly co-operation with the Local Committee, contributed to the courteous reception and the cordial entertainment of the members at this memorable meeting. No effort has been spared which could contribute to make every moment of our stay delightful and profitable; and we all feel that their efforts have been crowned with the highest success.

We desire especially to mention Professor Persifor Frazer, the Citizen Reception Committee, the Union League, the Franklin Institute, the Engineers' Club,

merican Philosophical Society, the Academy of Natural Sciences, the Penn-
nia Railroad Company, the Philadelphia and Reading Railroad Company,
ennsylvania Museum and School of Industrial Art, Mr. Samuel C. Perkins,
rman of the Public Building Commission, Mr. John McArthur, architect,
encoyd Iron Works, the Midvale Steel Works, Mr. J. Bishop, the Phila-
ia *Press*, the Baldwin Locomotive Works, Messrs. Whitney & Sons, and
Frederick B. Miles, and the Local Committee of Arrangements.

Ir. J. D. Weeks offered a resolution of thanks to the retiring
ident, Mr. William P. Shinn, for his useful services and skilful
agement of the affairs of the Institute during his term of office.
resolution was adopted by acclamation.

Ir. Shinn replied briefly to the resolution, thanking the members
heir support and co-operation, and then declared the meeting
urned.

PAPERS

OF THE

ANNUAL MEETING.

FEBRUARY, 1881.

ADVANCE IN MINING AND METALLURGICAL ART, SCIENCE, AND INDUSTRY SINCE 1875.*

BY WILLIAM P. SHINN, PITTSBURGH, PA.

seems proper to present in the *Transactions* of the Institute, time to time, formal record of the advances made in the arts sciences to which our organization is devoted—milestones in highway of progress—from which our successors may measure they in their turn have gained.

he admirable address of the Hon. Abram S. Hewitt, then presi- elect of the Institute, on "A Century of Mining and Metal- in the United States," read at the opening of the meeting held is hall in June, 1876, forms a point of departure, and the con- on of the eighth decade of the nineteenth century and the end e first five years of our country's second century seem to offer ing time for again making up our record.

he period since 1875 has been marked by a degree of activity in ng and metallurgical industry never before equalled in our his- while the progress made in the science and art has been, if ble, still more noticeable. Whether we consider the mining of ore, and coal, or of the precious metals,—the advances made in ting the former and in reducing the latter, the extraordinary in- e in the production of Bessemer steel, or the science of Thomas Gilchrist, which makes the hitherto rejected phosphorus the er-stone of success,—the past five years are alike memorable for progress they have shown; and to some of the most marked fea- of this progress I will now briefly call your attention.

may be of interest in this connection to note the following es, showing the growth of the population of the United States ng the last three decades:

Year.	Population.	Increase.	Per cent.
1850.	23,191,876		
1860.	31,443,321	8,251,445	35.6
1870.	38,558,371	7,115,050	22.6
1880.	50,300,000	11,741,629	30.5

* Annual address of the President of the Institute.

The table appended (page 299) shows the yearly production of the leading minerals and metals during the ten years ending with 1880.

COAL.

As coal is the very foundation of our craft, I will first consider what has been done in its development. The known area of useful and workable coal in the United States has been greatly extended since 1875 by discoveries in Utah, Colorado, Indian Territory, and New Mexico, good coking coals having recently been found in the two latter, which seem destined to open these territories very rapidly to metallurgical industry.

A comparison of the production of anthracite coal during the last five years with that of the preceding five years shows that there was mined of anthracite coal:

	Gross tons.
In 1871–1875,	104,655,254
In 1876–1880,	111,482,727
Increase,	6,827,473, or 6.51 per cent.

The great increase in the capacity for its production is shown by the output for 1879—27,711,250 gross tons—being 4,830,329 in excess of the largest previous output (that for 1873), or 21 per cent.

The total coal production of the United States is thus stated in gross tons:

	Anthracite.	Bituminous.	Total.
1870,	13,985,960	15,231,668	29,217,628
1875,	20,654,509	26,031,726	46,686,235
1879,	27,711,250	33,665,709	61,376,959

showing an increase from 1870 to 1879 of 109.7 per cent., of which two-thirds occurred since 1875.

The past five years have witnessed many improvements in the mining and handling of coal; notably in restricting the waste in the preparation of anthracite and in utilizing the culm, both by apparatus for burning it in its natural condition, such as that of Mr. John E. Wootten, applied to the engines of the Reading Railroad, and by forming it into bricks, in combination with clay or tar, as is done by the Delaware and Hudson Canal Company, and used on their locomotives. Machinery for washing bituminous coal for coking has been greatly improved, and a practicable arrangement has been devised for burning pulverized fuel which promises well. It is in the preparation by comminution, or by conversion to gas, that further economy in the use of fuel is to be looked for.

PIG IRON.

he production of pig iron in the United States for the periods ed aggregates as follows:

	Gross tons.
1871–1875,	11,233,424
1876–1880,	12,813,814
Increase,	1,580,390,
	or 14.07 per cent.

The production for 1880 is reported by Mr. James M. Swank as 35,191 gross tons, an amount 50 per cent. greater than the duction of 1872 and 1873, and over double that of 1876.

We are accustomed to regard the five years 1874–78 as years of at depression to the iron industry, and yet the product of pig iron those years was 10,652,836 tons, while it was for the ante-panic rs, 1869–73, 10,192,933 tons, showing an increase of 459,903 s, or 4.51 per cent. in the five panic years over the production the best five consecutive years ever known to the iron trade of s country.

The use of regenerative stoves with blast furnaces of large hearth ea has opened a new era in the history of blast furnaces, evidenced the product of the furnaces of the Edgar Thomson Steel Company, Limited, their "B" furnace of 20 feet bosh by 80 feet high ving averaged upward of 140 tons per day during a blast of seven onths, and having made 208 tons in 24 hours. That large blowg, combined with high heating capacity, in furnaces having large arths, will result in still greater production, with less consumption fuel per ton, seems assured in the early future.

IRON ORE.

The production of iron ore has received an impetus in the inreased production of pig iron, shown by the increased production f the Lake Superior region, as follows. The output for the fivear periods before referred to shows as follows:

	Gross tons.
For 1871–75,	4,779,114
For 1876–80,	6,453,092
Increase,	1,673,978,
	or 34 per cent.

The production for 1880 reached 1,975,602 gross tons, an amount xceeding by 800,000 tons the largest year's output prior to 1876, nd by 560,000 tons the greatest production of any previous year—hat of 1879.

WROUGHT IRON.

There has been a material advance in the production of the various forms of wrought iron, and some decided improvements in the economy of its production. The ordinary consumption of fuel per ton of iron puddled has been 3000 to 3200 pounds, but the Swindell regenerative furnace puddles a ton of iron with 1250 pounds of slack coal. Experiments now being made on a new revolving puddler promise even better results than this.

STEEL.

In the production of Bessemer steel there has been an increase as unexpected as it is extraordinary, whether considered in its commercial aspects or as the result of the skilful handling of machinery originally designed for a much smaller output, for it must be considered that up to the end of 1880 there has been no increase in number and very little in the size of converters since 1876. The output of Bessemer steel ingots was for the five years:

	Net tons.
1871–75,	907,060
1876–80,	8,950,954
Increase,	8,043,894, or 333 per cent.

The product of 1879 was 928,972 net tons, or 21,000 tons in excess of the five years 1871–75, while that for 1880 was 1,203,173 net tons, an amount greater than the output of any two years prior to 1878.

The output of ingots of some of the leading steel works during 1880 is reported as follows:

	Gross tons.
Edgar Thomson,	123,303
Cambria,	122,143
Joliet,	116,750
Lackawanna,	105,354
North Chicago,	100,178

Of steel rails there has been a more than proportionate increase, due to greater economy in the production, whereby a slightly larger percentage of rails has been obtained from the ingots than was previously done. The product for five years was:

	Net tons.
1871–75,	697,142
1876–80,	3,046,584
Increase,	2,349,442, or 335 per cent.

he steel rails produced in 1879 were 683,964 tons, nearly equal
ie five years 1871–75, while for 1880 there were made 967,592
, or 40 per cent. in excess of that five-year product.

he steel-casting process first adopted at Terrenoire is about being
oduced by Mackintosh, Hemphill & Co., Limited, of Pitts-
gh. The manufacture of steel castings is a growing industry,
bids fair to increase very rapidly.

he Krupp process of washing out phosphorus is in successful
ation at the Springfield Iron Company's works at Springfield,
and promises well in connection with the open-hearth process.

he Thomas & Gilchrist basic process is a commercial success
ad, and will doubtless soon be introduced in this country in new
ts now being constructed with Holley's plan for changing vessel
ls.

mprovement in the quality of Bessemer steel is to be looked for
ie direction of allowing time for the steel to settle, the ingredi-
to become more thoroughly distributed, the fine particles of slag
ise to the surface, and the free oxygen to escape before casting
ingots. The question of the removal of the occluded gases from
is also attracting attention abroad, and appears likely to affect
materially the quality of the ingot metal of the future. One
Edison's experiments with platinum wire, effecting what he calls
removal of the contained air, but which was evidently the re-
al of the occluded gases, raised the melting-point of the wire to
ole its original temperature, and increased its light-giving ca-
ty eight times.

is stated that the Wheeler process of rolling steel scrap in an
casing is being utilized at Chester, Pa., in the manufacture of
plates.

GOLD AND SILVER.

he product of the precious metals for the periods named was as
ows:

GOLD.

1871–75,	$197,662,244
1876–80,	196,690,603
Decrease,	$971,641

SILVER.

1871–75,	$133,607,510
1876–80,	206,210,848
Increase,	$72,603,338

The product of the two precious metals showing an increase of $71,631,697.

The great increase in the output of silver is largely due to the great carbonate deposits of Colorado, the product of the Leadville mines in 1879 being $10,189,521, and in 1880, $15,095,153.

PETROLEUM.

The mining product showing the greatest increase in output is petroleum, which was:

	Barrels.
In 1871–75,	41,911,367
In 1876–80,	83,042,121
Increase,	41,130,754,
	or nearly 100 per cent.

The production in 1880 reached the enormous total of 26,032,421 barrels, compared with which the greatest year's output prior to 1876 was 10,910,303 barrels in 1874.

MACHINERY.

There have been great improvements in mining and metallurgical machinery during the last five years, prominent among which may be mentioned the Porter-Allen high-speed engine for rolling-mills; the Leavitt compound engine for pumping and hoisting, of which the Institute saw good specimens in its visit to Calumet and Hecla during the Lake Superior meeting; the Bulkley condenser, which is coming into general use for rolling-mill and blast-furnace engines; and the Kloman eye-bar universal mill, for producing weldless eye-bars of iron and steel, the only process so far used adapted to eye-bars of Bessemer steel.

RAILROADS.

Much of the increased output of iron ore, pig iron, and steel rails is due to the demand created by the construction of railroads, of which there have been 19,397 miles constructed since 1875, and of which 7150 miles were built in 1880, an amount nearly equalling the mileage of 1872, which was 7340 miles.

GENERAL REMARKS.

Of course it would be presumptuous to claim all of this improvement to the operations of this Institute, and yet I have no hesitation in saying that a considerable proportion is due to our members;

, as regards the quantity of output; and, second, as regards nomy of production—more especially the latter. We all know to several of our members is due the great improvements in the ease of output in the Bessemer process, and to the work and ights of others are due many other advances in the metallurgical . I trust that my successor five years hence may be enabled to as good an account of the next five years as I have of the five passed.

TEMENT OF ANNUAL PRODUCTION OF LEADING MINING AND METALLURGICAL PRODUCTS, DURING THE TEN YEARS 1871–80.

Anthracite coal. Gross tons.	Pig Iron. Gross tons.	Bessemer steel ingots. Net tons.	Steel rails. Net tons.	Gold.	Silver.	Petroleum. Barrels.	Lake Superior region.	
							Ore. Tons.	Pig. Tons.
17,379,355	1,707,685	48,850	38,250	$35,898,000	$20,286,000	5,795,000	813,379	51,225
22,084,083	2,539,783	120,108	94,070	39,459,459	20,527,500	6,539,103	952,055	61,195
22,880,921	2,560,962	170,652	129,015	40,456,593	28,252,100	9,879,455	1,167,379	70,507
21,667,386	2,401,261	191,933	144,944	40,103,045	30,498,000	10,910,303	935,488	86,494
29,643,509	2,023,733	375,517	290,863	41,745,147	34,043,910	8,787,506	910,840	81,753
104,655,254	11,233,424	907,060	697,142	$197,662,244	$133,607,510	41,911,367	4,779,141	351,174
19,000,000	1,868,961	525,996	412,461	$44,328,501	$41,506,672	8,968,906	977,233	61,911
21,323,000	2,066,594	560,587	432,169	45,300,000	46,075,000	13,135,671	960,982	29,685
18,600,000	2,301,215	732,226	550,398	41,000,000	40,000,000	15,163,462	1,123,093	17,404
27,711,250	2,741,853	928,972	683,964	32,539,920	38,623,812	19,741,661	1,414,182	39,583
24,848,477	3,835,191	1,203,173	967,592	33,522,182	40,005,364	26,032,421	1,975,602	48,502
111,482,727	12,813,814	3,950,954	3,046,584	$196,690,603	$206,210,848	83,042,121	6,451,092	197,085

THE ACTION OF COMMON SALT AND OTHER RELATED CRYSTALLINE SALTS IN WIRE-DRAWING.

CHARLES O. THOMPSON, OF THE WORCESTER (MASS.) FREE INSTITUTE.

WHEN a wire rod of iron or of steel is immersed in a hot solution ommon salt, allowed to remain long enough to bring the metal to temperature of the brine, and withdrawn, the surface of the is irregularly covered with a deposit of crystals of salt. These tals adhere to the rod with great firmness, in consequence, btless, of a thin film of ferric hydrate, which is formed between n and the rod as the water dries off. The rod can now be re- ed, by successive passes through a die or draw-plate, without any

abrasion of the die. The economical advantage of this novel lubrication of wire is at once apparent, and the principle involved in it is interesting.

The investigation of this principle was begun by the writer in February, 1879, and has been continued till the present time, and some of the results are embodied in this paper.

Several facts were established by observation:

After the first passage of the rod through the draw-plate the salt, easily detected by taste, is totally invisible; the addition to the brine of a small volume of lime-water seems to promote the lubricating action of the salt; hard steel rods are more successfully drawn than soft iron, and the harder the better; the hot brine is not the only way of applying the salt, although preferable, for when the hole in the draw-plate is stuffed with salt, or when salt is dusted on to the wire behind the die or made to adhere by oil, or when the wire is passed through fused salt, the same results, substantially, are obtained.

These observations suggest the questions: What is the action of the salt? Is it chemical, physical, or both?

To determine this point, a large number of experiments were instituted, some of which are given:

A. A coil of steel rod, diameter .192″, salt-coated, was reduced by six consecutive passes, without annealing, and the last foot taken from each pass.

The diameter was reduced from .192″ to .078″.

At the seventh pass the wire broke.

The wire-gauge showed that the diameter of the wire remained constant throughout each pass.

These pieces were separately digested in warm water for a sufficient time to effect a perfect solution of all soluble matter that adhered to them. The total amount of salt adhering to each piece was in

No. 1,	0.0064	gram.
" 2,	0.0030	"
" 3,	0.0019	"
" 4,	0.0016	"
" 5,	0.0013	"
" 6,	0.0011	"

B. Another set of six pieces, taken under conditions identical with those in A, showed similar results, the salt per square inch being in

No. 1,	0.00110 gram.
" 2,	0.00060 "
" 3,	0.00044 "
" 4,	0.00040 "
" 5,	0.00039 "
" 6,	0.00039 "

C. To ascertain whether there was any inequality in the distribu- n of the salt-coating over different parts of the same coil, another of samples was taken, under similar conditions, except that the *two* feet were substituted for the first foot in each case.

	Reduction in diameter.	Total salt on two feet of wire, in grams.	Salt per square inch, in grams.
No. 0,		0.19870	0 01390
" 1,	from .192″ to .154″	0.01477	0.00127
" 2,	" .154″ to .131″	0.00499	0.00050
" 3,	" .131″ to .113″	0.00288	0.00033
" 4,	" .113″ to .102″	0.00299	0.00036
" 5,	" .102″ to .092″	0.00259	0.00039
" 6,	" .092″ to .078″	0.00156	0.00027
" 7,	" .078″ to .067″	0.00156	0.00027
" 8, wire broke.			

This was the largest number of consecutive passes obtained in the periments.

Comparing these results with A and B, it is seen (a) that the total adhering to the wire tends to become uniform at the fifth pass, ugh the amounts brought from the brine by the rods are unequal; that the amounts of salt per square inch vary as the sizes of the e; (c) that the amount per square inch also tends to become con- nt at the fifth pass.

But the most important result of these experiments is that *not a ce of soluble salts of iron* could be found in any of the waters in ch the samples were digested. In fact, no chemical action on the can be detected except that already alluded to, whereby a cement formed by the oxidation of the iron, which undoubtedly serves bind the salt more firmly to the wire.

The cause of the formation of the continuous, adhesive, trans- ent coating of salt on the wire as it emerges from the draw-plate st be sought in the intense pressure to which the wire and the are subjected and the high temperature caused by this pressure. e exact temperature of the draw-plate at the point and moment of tact between it and the wire cannot be easily determined. The perature of the wire at the instant of emergence from the draw- e has been experimentally determined to be at least as high as

the fusing-point of tin, *i. e.*, 237° C. This combined heat and pressure cause the particles of salt to run together and to form a complete plastic, coherent sheath around the wire.

That a brittle, crystalline solid, like common salt, should be capable of becoming plastic, or that its molecules should assume the degree of mobility sufficient to form a coherent fluent covering to the wire, appears at first sight anomalous. Nevertheless the experiment affords complete proof that such is the case. Nor is analogy wanting.

No natural phenomenon has been more carefully and accurately studied, both in the laboratory and on a grand scale in nature, than the regelation of ice—itself a brittle crystalline solid. It is a well-known fact that fragments of ice, at temperatures far below the freezing-point of water, can, by pressure, be made to cohere so completely that no traces of lines of union remain, and that masses of ice may flow with almost the facility of liquid water.

It cannot be affirmed that this property of regelation belongs exclusively to ice, though it may not have been heretofore observed in other solids. Experiments seem to show that it is a property of all crystalline fusible bodies. It has been proven that some solids, like salt, form a coherent, transparent, plastic envelope, while others, like alumina, do not. To the former class belong only those crystalline compounds which are fusible; to the latter belong those bodies which are either infusible or amorphous, and which, consequently, do not possess the property of regelation when exposed to pressure and high temperature.

The temperature and pressure necessary to complete fluidity of any substance are, without doubt, inversely related to each other. But it is not necessary to assume that the salts employed are ever actually fused in the process of wire-drawing, as experiments show, for this phenomenon of regelation is one which takes place at temperatures below fusion. Common salt, the most available of all substances thus far tried, fuses only at a red-heat.

In drawing wire it is desirable to reduce, as much as possible, the friction between the wire and the draw-plate. When salt is used, the plastic sheath which is formed interposes itself between the wire and the draw-plate, thus allowing the wire to pass through without coming in actual contact with the surface-wall of the draw-plate.

It is also plain that an ordinary lubricant like oil may be advantageously applied outside the sheath of salt. The actual practice, therefore, is to have an iron or steel wire, protected by a tenacious,

rent sheath of a crystalline compound, which sheath is itself unded with an ordinary lubricant.

n interesting question arises at this point, Whether the wire slips e salt sheath, or whether the whole combination is drawn out her? The experiments in C are decisive in favor of the uni- elongation of the sheath with the wire, till it finally becomes so as to be incompetent to protect the wire.

nother inquiry is, What is the auxiliary action of the lime which vantageously added to the brine? It has long been known when wire which has been cleaned in chlorhydric acid is im- ed in lime-water it receives a coating which permits two or consecutive reductions. This is obviously due to the forma- of a small amount, in each case, of calcium chloride, which acts salt. But in the case of the joint action of salt and lime-water ire which has been washed in sulphuric acid, it seems probable he lime merely promotes the slight oxidation of the wire by h the coating is cemented to it. The small amount of gypsum h might be formed will not act as an addition to the protecting h.

confirm the theory of regelation,* as now presented, I insti- the following experiments:

he ends of two similar solid, hard, steel cylinders, $\frac{3}{8}''$ and $\frac{1}{2}''$, carefully finished. As much salt as it would hold up was upon one, the other set upon it, and the combination subjected vertical pressure of 192,000 pounds per square inch. At the nt of maximum pressure the cylinders "buckled," and a thin parent sheet of salt gushed from the convex side.

he experiment was immediately repeated without accident, and lifting off the upper cylinder, when the couple was removed the testing-machine, the whole of the salt was easily removed thin, transparent, coherent wafer. The transparency was so ct that a mark of a No. 4 Faber pencil was seen through the with ease.

he results of numerous experiments with other crystalline lubri- , and of an investigation of the effect of intense pressure on crystalline bodies, may form the theme of another paper.

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his theory of the "regelation" of the salt subjected to heat and pressure, ng a plastic sheath around the wire, and acting therefore as a "solid lubri- " was suggested by Dr. T. M. Drown, of Lafayette College, Easton, Pa., vas associated with me in a day's experimenting with the salt process, at orks of the Washburn & Moen Manufacturing Company, in Worcester

AN ORE-ROASTING FURNACE.

BY W. J. TAYLOR, CHESTER, N. J.

SOME eight years ago I became interested to a considerable extent in one of the well-known deposits of sulphury iron ore in New Jersey, and, as a consequence, soon became interested in the subject of the elimination of the sulphur.

On investigation I found that no department of pig-iron manufacture had received less attention than that of roasting or calcining ores for the elimination of sulphur, carbonic acid, water, etc.

My first devices to eliminate sulphur were naturally in the lime-kiln line, with solid fuel mixed with the ore, in the same way as common lime is burnt with small coal. While this process will succeed tolerably well for carbonates or calcareous ores, even though they contain sulphur as sulphates, I soon found it would not answer for our magnetites, which are very hard and dense, carrying from 2 to 5 per cent. of sulphur as pyrites, and become very sticky as soon as any attempt is made to roast them at a high heat.

Some laboratory experiments developed the fact that the nearer the gaseous current surrounding the hot ore approached in composition pure atmospheric air the more rapidly the sulphur was oxidized, while in an atmosphere composed largely of carbonic oxide, carbonic acid, and nitrogen, it seemed almost impossible to reduce the sulphur more than one-half, which was a confirmation of the well-known fact that just one-half of the sulphur in pyrites volatilizes very easily, and that the trouble is mainly to remove the remainder. It was thus apparent that the atmosphere surrounding the ore was of as much importance as the temperature.

This led to the trial of a kiln to heat the ore by conduction through the brick. It was divided into ore-chambers, which were surrounded with flues, through which the products of combustion of gaseous fuel passed without coming in contact with the ore. We did not, however, succeed by this arrangement in getting more than a cherry-red heat, which, of course, was too low to accomplish anything.

I had at this point become convinced—

1st. That *gaseous* fuel only would accomplish the work successfully.

2d. That since a *high temperature* was required to insure a rapid oxidation of the sulphur, and also to make the ore open and porous,

s absolutely necessary to so construct a kiln that *one could ol the process by having access to the ore* during the whole time ained in the kiln, more particularly in the hot zone.

That since the elimination of sulphur is so imperfect, even igh temperature, while the ore is in contact with the gaseous cts of combustion, *the ore should be withdrawn from such contact n as possible after it had attained the necessary temperature.*

t while we had progressed far enough to learn what we wanted , we were yet at a loss to know how to do it. I had heard kiln, known, I think, as the Hudson kiln, which was a kind s kiln, consisting of a vertical shaft about eight feet diam- and surrounded with chambers near the bottom for firing coal in front of the ore, for the purpose of heating it, instead rning coal mixed through the ore. This kiln was tried quite sively some six or eight years ago, but seemingly without results. The heat of the fire-chambers having been insuf-t, coal was mixed with the ore, resulting in the same difficul- s have been experienced in other attempts of this kind. There oo little heat in one place, and too much in another, with con- nt clinkering and all the usual difficulties of the ordinary lime- practice, aggravated by the obstructions which the firing-cham- pposed to punching and working the ore at the most important

e Westman Swedish kiln was the only real gas kiln then in ut only one had ever been built in this country to my knowl- and that was used very little. All the kilns in use in Sweden run with furnace gas as far as I could ascertain, and I could o data as to the amount of gas required. The expense of ing seemed to be excessive when roasting magnetic ores, which icky at high temperatures, and much labor was required in ning to work the ore down, causing irregular dropping, and, quently, allowing more or less poorly-roasted ore to come gh, which had to be sorted out and put back. The Swedish s simply a vertical shaft with gas jets entering all around it he bottom, with but little or no arrangement for facilitating ustion.

ould here remark that, as far as my experience goes, compara- no gas is burned after it enters the ore, even if it is hot and esent, analyses having shown that gases only partly burned e entering the hot ore contained no more carbonic oxide than caping gases above the ore.

The ore in the centre of a Swedish kiln in operation remains stationary, forming what may be called a cone, between which and the inside of the outer wall all the roasting is done; or, in other words, the ore is roasted in the annular space of say 16 to 24 inches, formed by this cone and the inside of the outer wall.

I tried this plan, with a brick instead of an ore centre, but with all the producer capacity we could command we could not make gas enough to heat over five or ten tons of ore per day, which convinced me that great improvements must be made in gas consumption before we could roast ore successfully with producer gas.

The first improvement was to utilize for a combustion-chamber the centre, which, in the Swedish kiln, is dormant. The second was to divide the annular space, thus formed, into vertical ore-chambers, so that the ore could be dropped in sections, by radial piers, through a flue, in the top of which the hot gases from the combustion-chambers could be discharged. The third was to offset the inside of the outer wall inward, forming with the slope of the ore a triangular flue on the outside of the chambers, which was connected directly with the flues through the radial piers, thus enabling us to burn the gas in the centre and discharge it into the ore from the outside, where the temperature and working of the kiln can be watched, without any obstructions of gas-pipes, fire-chambers, etc., to prevent the working and punching down of the ore.

This triangular, or what we call the circulating flue, presents an exposed face of ore for heating on a slope of, say 45° for about 12 inches and from side to side of the ore-chamber, the outside wall of the kiln opposite the ore-chambers being a series of arches, one above the other, to give access for punching and working.

This is a general description of the kiln or furnace as we worked it up to last summer; but it was still far from satisfactory, on account of the arches forming a lodgement for clinkers which required too much labor to work down, besides causing irregular dropping, and thus allowing more or less ore, not properly heated, to pass the heating zone.

My assistant, Mr. N. M. Langdon, finally designed the modification of the ore-chambers now in use, as shown in the accompanying drawings.

The front or outer walls are corrugated or made convergent, and at the angle thus formed are placed the working openings, suitably protected with castings of iron, in this way avoiding the obstructions caused by the arches to the downward passage of the

, and at the same time giving as good, if not better, access with a rking bar to the ore, in all parts of the chamber. We are thus

FIG. 1.

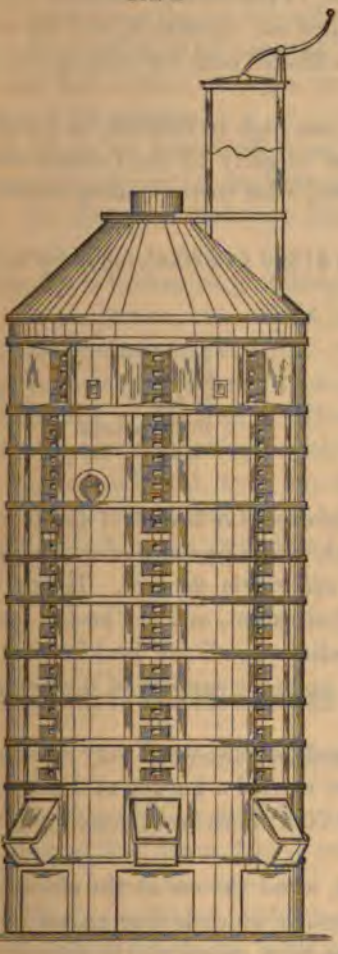
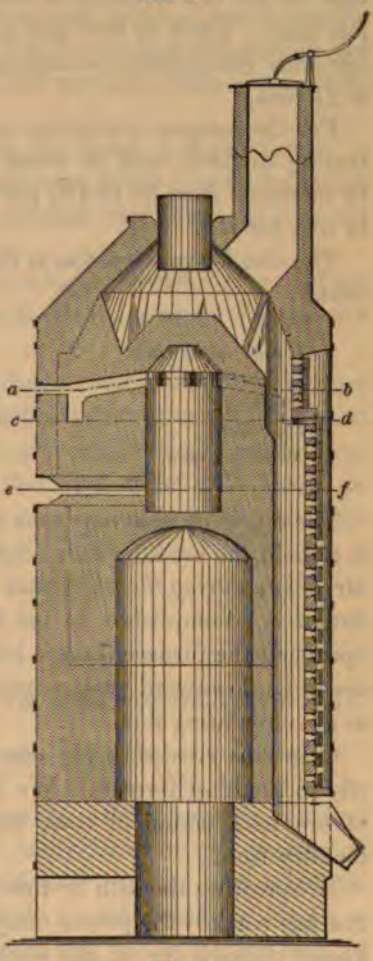
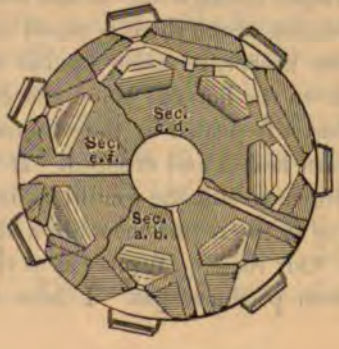


FIG. 2.





enabled to drop the ore uniformly and with comparatively little labor. We have no trouble now in roasting in the best manner 50 tons per day in a seven-shoot furnace, 14 feet outside diameter, and 36 feet high. Three to four men on turn can operate it, and the average daily consumption of anthracite broken coal, for making the gas, is 2¼ tons.

For the purpose of roasting ores less high in sulphur, or for eliminating carbonic acid or water, the capacity of the furnace would be increased from 50 to 100 per cent., with corresponding reduction in cost per ton.

The cost for construction is from $1800 to $2000, made up as follows:

Rough stonework, ...	40 cubic yards.
Red brick, ...	46,500
Firebrick, ...	16,500
Cast iron, ...	16,500 pounds.
Wrought iron, ...	4,250 "

The object of what may seem to be excessive height of the furnace is to hold the ore after being heated, in the presence of atmospheric air only; *during the whole time it will retain its heat.* Hence oxidation is accomplished to the fullest extent, and no heat is lost in operating the furnace (except by radiation), all the heat leaving the ore in its downward passage going up to the support of the hot zone at the circulating flue.

Ores thus roasted, being open and porous, work very satisfactorily in the blast furnace. We have carried a burden of 1.8 pounds of ore to 1 pound of coal, with 700° blast-heat, making No. 2 foundry iron.

In operating the kiln or furnace, when the ore at the circulating flue has reached the proper temperature (which is determined by the keeper through one of the working-holes opposite), the gate at the bottom of the shoot is raised and a portion of ore withdrawn. Then the keeper, by using his bar through the working openings, brings down the hot ore below the heating zone, and the ore from above, partially heated by the escaping gases, takes its place, to be in its turn heated and dropped. It will thus be seen that the ore must be drawn to suit the conditions in the roasting furnace, and not according to the requirements of a blast furnace.

Our roasting furnace is at the mines, and we have always run it with producer gas. I have little doubt, however, but that most

t furnaces could spare enough gas to roast all the ore they use in way.

Ve have never been able to reduce the sulphur below 0.10 per ., even when the ore was almost entirely oxidized, but it usually from 0.30 to 0.40 per cent. With ½ per cent. sulphur in the our iron seldom contains over 0.05 per cent., with silicon from to 1.50 per cent.

s far as my experience goes I do not think it is practicable to ce the sulphur in our high sulphurous, dense magnetites below per cent., and from my blast-furnace experience it does not n necessary.

ur ore is broken to go through a 4-inch diameter ring. Much ore is objectionable. The kiln will not drive when the quantity exceeds 5 or 10 per cent.

s regards wear and tear I am of the opinion, from the experience ave had so far, that a well-constructed furnace would run at one year continuously without any repairs worth mentioning, if the inside was worn out by that time, about $400 would be expense of making it good; so this amount would cover the r and tear on say 18,000 tons ore, or 3 cents per ton.

LUXING GAS-PRODUCER FOR MAKING HEATING GAS.

BY W. J. TAYLOR, CHESTER, N. J.

making heating gas with anthracite coal for roasting ore dur- he past few years, I have tried many forms of gas generators. ar, the most successful and satisfactory one has been what we a fluxing producer, which is simply a small cupola or blast fur- , in which we charge with the coal, say, 30 or 40 per cent. of blast-furnace cinder, to unite, when melted, with the ash or y matter in the coal, and carry it off as cinder. The producer ave in use at Chester, N. J., has more of the lines of a blast fur- than a cupola, the hearth being 24 inches diameter and 24 s high. It then enlarges on an angle of about 25 degrees from pendicular to 4 feet, and then is drawn into 3 feet on top; total t, 12 feet. We use one water coil-tuyere 12 inches above the m, and blow through a 1½-inch nozzle. The depth of coal e the tuyere averages about 6 feet. The producer is blown with

a small Weimer blowing engine 24 inches diameter and 12 inches stroke, delivering six cubic feet of air to a revolution, or 300 feet of air per minute. It consumes, say, 200 pounds of coal per hour, which is about 80 feet of air for 1 pound of coal. The air pressure is from 1 pound to 1½ pounds to the square inch. The cinder is tapped out about every two hours, and is black and glassy. In this way we get a continuous flow of gas as long as the engine is kept running. We have run for at least four weeks without a moment's stoppage or change of any kind. We depend upon cinder mainly for fluxing, and though we often use a little limestone with it, we have never tried to do without cinder entirely. The only fuel used so far has been anthracite coal, broken or egg sizes giving the best results. We have not been able to make fine anthracite work at all. I have no doubt that almost any kind of bituminous coal could be used, if not too fine.

The advantages in favor of this producer are:

1st. It makes an excellent gas, very uniform in quality. There is so much incandescent fuel above the tuyere that no air can escape unconsumed, and the gas is almost entirely free from carbonic acid.

2d. There is no cleaning of ashes to be done, consequently there is no cessation of the flow of gas and no waste of coal,—a very important matter.

3d. The quantity of gas from this producer can be increased by simply increasing the volume of air entering it, and any one familiar with blast-furnace practice can run it, particularly if cinder for fluxing is available. The power required for blowing the producer for burning 200 pounds of coal per hour is, say, 45,000 foot-pounds or 1½ horse-power, which, at 3 pounds of coal per horse-power per hour, would amount to 2½ per cent. of the coal burned in the producer.

GAS-PRODUCERS USING BLAST.

BY F. H. DANIELS, WORCESTER, MASS.

In this paper it is my intention to call your attention to a few of the many producers using blast, now in common use in Sweden, and also those constructed by the Washburn & Moen Manufacturing Company at their Quinsigamond Works.

During a prolonged stay in Sweden the writer had an opportunity

udy and examine the various metallurgical processes and opera- as conducted in that well-known iron-producing country. One ie greatest obstacles Sweden has in the way of leading the world e iron manufacture is the great scarcity of native fossil fuel, h is only found in very small quantities and of very poor quality ie south of Sweden. The Swedish ironmasters are therefore ed to use all kinds of combustible materials for producing gas used in the Siemens heating and Martin steel furnaces. Hence ucers of special design adapted to the different kinds of wet have been constructed, and at the present time are in use all over len, giving very satisfactory results.

ie following fuels are used: sawdust, wood, peat, charcoal, and minous coal. Charcoal is at the present time but little used on int of its extra cost and exceptionally good quality for other oses which require a very pure fuel; but when it is used it is nouly mixed with peat, wood, or bituminous coal. The ques- of cost also affects the use of bituminous coal, which is imported ly from England, and the transportation to many of the works ted in the interior is very expensive. Sawdust is used directly comes from the saw-mills, or from the storehouse where it has mulated, and it is seldom mixed with other fuels. Wood in- es slabs and all refuse from the saw-mills and trimmings from brest trees, such as limbs and branches which are too small to nverted into charcoal. There is a great abundance of peat in of Sweden, which is cut in early summer and stored in houses fficient quantities for the years' supply; it is air-dried as much ssible, but even then contains 25 to 80 per cent. of water, de- ing upon the kind of drying weather during the summer. It d seem that nothing of a combustible nature is allowed to be ed. Everything that will burn is gathered into storehouses and as fuel for the various metallurgical operations requiring gas.

ll of these materials contain more or less water, as high as 80 ent. in peat. On this account much difficulty has been found oducing gas without the use of blast, and at present blast has adopted both for the gas-producers and furnaces, the common ure being from 0.2 to 0.4 of an inch of mercury, and some- s even higher. But it is a fact that the higher the pressure the er the gas, and for this reason it is rarely increased above 0.4 of ch.

free the gases from the steam which is generated with these , which all have more or less water, the producers have con-

nected with them condensers, which in many respects are similar to the ordinary jet condenser of the steam-engine. The results are very good; the gas passes from the condenser practically free from moisture but with the loss of the condensable hydrocarbon gases, which are of small quantity in the fuels above enumerated. Within a few years the Swedish Commission upon fisheries have found that the products of condensation have so contaminated the streams and lakes as to destroy the fish in large numbers, and many works have been obliged for this reason to put in surface condensers, which give equally good results but are more expensive and troublesome, owing to the flues filling up with tar, and the necessity of disposing of the condensed products.

The gas as it passes from the condenser is dry and clean, and always under the pressure due to the blast, which can be regulated as desired. The conductors to the furnaces are free from tar and other obstructing matter, and the troublesome operation of burning-out is thus avoided. At many works the gas flues are made out of wood put together in a cylindrical form with iron hoops, making a very durable and cheap conductor, and without any trouble from leakage.

The leading types of gas-producers now in use in Sweden may be classified in a general way as follows:

1st. Producers using sawdust.

2d. Producers using short wood.

3d. Producers using long wood.

4th. Producers using peat, with wood or coal, or all three mixed.

Sawdust, short wood and long wood are almost always used separately and constitute the fuel for the first three classes, while peat is almost always mixed with short wood, and at many works with bituminous coal. The accompanying drawings illustrate in a general way the different kinds of producers as now in use.

1*st. Producers using Sawdust as a Fuel.*—On Plate I is shown a producer which is in operation at the Domnarfvet Iron Works near Falun, in Dalecarlia. Fig. 1 is a longtitudinal vertical section through the producer and condenser on the line A B. Fig. 2 is a plan and horizontal section at C D and E F. Fig. 3 is a near view. Fig. 4 is a front view. The form is cylindrical and is composed of an outside shell of boiler plate 8 feet in diameter and 14 feet high. This is lined with one course of firebrick 6″ thick. Blast is brought in under the grate by the pipe A, and the ash-pit is arranged with two doors, one for the removal of ashes and the upper one for cleaning the grate; there is also a poke-hole, B, for the removal of scaffolds

e gas passes out at C directly to the condenser D, and is there ught into contact with a spray of water from the water-pipes E. e condenser is composed of cast-iron plates, put together as shown Figs. 1 and 2. The condensed products with the condensing ter fall into the canal F, and the level of the water is retained h enough to prevent the gas escaping, as shown in Fig. 1. The passes off from the condenser with two exits. The pipe H is d for the escape of the gas while firing or lighting up, and until gas is of good quality, when it is turned into the other connect- with the main gas flue I, which conducts the gas to the furnace. e fuel, obtained from the company's saw-mill near by, is charged depth of about 6 or 7 feet above the grate. The gas is used in ting and Siemens-Martin steel furnaces. Great care must be taken he management of this class of producers, as explosions are liable happen if they are not properly managed, owing to scaffolds form- and falling in and allowing the air to mix directly with the gas.

2d. Producers using Short Wood as Fuel.—Figures 5, 6, 7, 8, on te I, show a producer used by the Uddeholm Company at their nkfors Works. Fig. 5 is a vertical section on line A B. Fig. 6 vertical section on line C D. Fig. 7 is a plan and Fig. 8 a hori- tal section at E F. The base of the producer in horizontal section 1 feet square and 8 feet high, above which the form is cylindrical, ng 11 feet outside diameter and 9 feet inside diameter, the total ght of the producer being 22 feet. The outside course of masonry composed of brick cast out of heating-furnace cinder, which is d very much at these works for building purposes. The outside ll is lined with red brick at the base and top, and finally with six-inch course of firebrick. The producer is held in shape by ought-iron rings and tie bars as shown in Figs. 5 and 6. The st is brought in by the pipe A, and distributed into the several -pits B B (Fig. 8), which are separated from each other by par- on walls C C. There is one door for two ash-pits, and it is pro- ed with a poke-hole D, and a peek-hole E. Water is circulated ough the pipes F. The gas passes out by the pipe G directly to condenser, which is similar to that in Figs. 1 and 2. The fuel is ut 16 feet deep and is composed of the waste short wood, about 1 2 feet long, from the company's saw-mills. They have also at the e works producers for sawdust and long wood. The gas is con- ted through wooden pipes, about two feet in diameter, and is used hree four-ton open-hearth steel furnaces, and a number of heat- furnaces.

3*d*. *Producers using Long Wood as Fuel.*—Figures 9, 10, 11 and 12, Plate I, show a producer also in use at Munkfors. Fig. 9 is a vertical section at A B. Fig. 10 a section of charging device Fig. 11 a vertical section at C D. Fig. 12 a horizontal section at E F and G H. The horizontal section is rectangular and the outside dimensions are 11′ wide and 17′ long, and the inside dimensions 9′ wide and 15″ long. The cross-section on the line B B is very much like the corresponding section of the producer for short wood; the blast is brought into the several ash-pits as shown in Fig. 11, and the general arrangement is like the producer for short wood. The fuel in long pieces is charged in at the two openings A A, also short fuel by the two charging hoppers on top of the producer. The arrangement for preventing the escape of gas while charging the long wood is very ingenious the operation being as follows: Just before charging blast is let on by the pipe B, and is conducted into the charging opening C by the thin annular opening at D, but not with a pressure sufficient to lift the valve E and let the air into the producer. The door F is opened and the stick of wood quickly pushed in, which opens the valve E. The air meets the gas, which prevents its entrance into the producer in any appreciable amount, and at the same time completely prevents any escape of gas, the air escaping out of the open door. After the charging is finished the blast is shut off. The gas passes out by the openings F F into the condenser. Very much trouble was experienced with this kind of fuel and very many explosions resulted but the experience was soon gained, and for several years this fuel has been used with perfect success, saving the expense of cutting the slabs into short pieces.

4*th*. *Producers using Peat, with Wood or Coal, or all three Mixed.*—Figures 13, 14, 15, Plate II, give a good illustration of this kind of producer, which is in operation at the Bofors Company's Works, in Wermland. Fig. 13 is a vertical cross-section through two producers and their condensers and the producer-house on line A B and C D. Fig. 14 is a longitudinal vertical section through the condenser and producer-house on line E F, and Fig. 15 is a horizontal section at G H and I K. The outside shell is composed of brick cast from blast-furnace slag and is 12 inches thick; this is lined with 6″ of firebrick. There are four ash-pits, each of which is supplied with blast from the pipe A, and is brought in at B. C is a cast-iron water-bosh through which cold water is circulated. The charging operations consist of the cone D, and cover E, which is sealed with water when in place. The

s passes out by the cast-iron pipes F into the condenser, and as it sses downward comes in contact with the shower of water from e pipe G, passing into the central passage H, common to both pro-cers, and finally into the main flue I. The condenser is constructed irely of blast-furnace slag brick. Fuel is brought to the top of e producer by the inclined railway J. The car is drawn up by a ain wound upon the drum and driven by the shaft K. The cost these producers with the building was very small, being con-ucted almost wholly of blast-furnace brick. The producers supply o three-ton open-hearth steel furnaces.

The Washburn & Moen Manufacturing Company have con-ucted ten gas-producers from designs by Mr. Charles H. Mor-n, superintendent, which in many respects are similar to the edish producers. They are illustrated by Figs. 16, 17, 18, ate II. Fig. 16 is a cross-section on the line A B. Fig. is a longitudinal section at C D. Fig. 18 is a plan and rizontal section at E F and G H. The fuel is brought from the l-bank in cars by a narrow-gauge railroad, and the car is hoisted the hydraulic elevator A to the charging-floor, where it can be n the whole length of the building upon a track which is built on trestle-work five feet above the charging-floor. The fuel can dumped opposite any of the producers by withdrawing the latch ich holds the hinged bottom of the car, and in sufficient quan-ies for the night's supply. The producer is composed of a wrought-n shell $\frac{3}{16}$″ iron, 7 feet diameter and 12 feet high. It is lined th one 9″ course of firebrick, with a sand-space outside. The -pit has two doors opposite each other, and the blast is brought by the pipe C and under the grate at H. The gas passes out rough the cast-iron pipe E (which is provided with a valve F), o the main gas-flue, which is about 80 feet long and 3 feet in meter, and the expansion is so great as to prevent rigid con-ction with the cast-iron pipe E. To overcome this the pipe E s cast to it a circular pipe which drops into the annular space in cast-iron ring bolted to the main flue, the annular space being le enough to allow of 2 inches movement each way. After the nular space has been filled with sand, the joint is made, and the e free to expand. The fuel is charged into the upper hopper, pped into the lower hopper, and then into the producer, as shown I. This method prevents a very great loss of gas, which is of siderable account, since the gas is under pressure. These pro-cers have been using anthracite, anthracite and bituminous

coal mixed, and bituminous coal, and have been giving good re sults, but the writer is unable to say which fuel gives the mos economical results. They are now worked with bituminous coa with a pressure of blast from .1 to .2 inches of mercury. These pro ducers have been in operation for one year, supplying one larg Siemens reheating furnace for 21-foot billets and a furnace for re heating charcoal blooms. Blast is also used in the furnace at th same pressure as at the producers, both being supplied from th same blower. The writer is much indebted to Mr. Charles H Morgan for drawings and assistance.

NOTE ON THE ESTIMATION OF COPPER IN SPEISE.

BY F. C. BLAKE, MANSFIELD VALLEY, PA.

THE best method for the estimation of copper in ores and second ary products is that proposed by Dr. Steinbeck* for the award offere by the Mansfeld'schen Ober-Berg-und Hütten-Direction. It i based upon the decolorization of the blue ammonia solution of cop per by potassic cyanide.† It is necessary for the accurate estimatio of copper in arsenides that the arsenic be separated from the coppe before the ammonia solution is made. The presence of a notabl amount of arsenic renders the titration by potassic cyanide inaccu rate, the end reaction being obscured by the appearance of a yellow ish-green tint towards the end of the titration. The change of th color of the ammonia solution from blue to the tint caused by th presence of arsenic cannot be used for an end reaction, for the inten sity and quick appearance of the latter color depend upon the amoun of arsenic present in the solution.

In the analysis of speise, the method of separating the copper b an oxidizing and reducing treatment in the muffle, to volatilize th arsenic, gives poor results, and there may easily be some loss of th weighed sample. The separation of the precipitated sulphides o arsenic and copper by treating with sodic sulphide, gives good re sults, but the process is tedious.

I have used the two following methods, which are simpler an more expeditious than those mentioned, with good results.

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* Fresenius, Zeitschrift für Anal. Chemie., viii, 1.

† First noted by Parkes in the Mining Journal for 1851.

A. The weighed sample of speise is heated first with sulphuric id (concentrated acid diluted with about an equal portion of water), hich will not usually effect complete solution; sufficient concen- ated nitric acid is then added to produce complete decomposition the speise. The solution is then evaporated for half an hour or a tle longer after fumes of sulphuric acid appear, then diluted with ater and the copper precipitated by metallic zinc for re-solution; , if comparative results only are needed, the acid solution is treated rectly with ammonic hydrate. The amount of arsenic present in e final ammonia solution will not be sufficient to interfere with the ration by potassic cyanide.

B. The weighed sample is fused in a porcelain crucible with otassic or sodic bisulphate until completely decomposed. The fused ass is then dissolved in hot water. The solution will contain too tle arsenic to affect the end reaction in the ammonia solution.

This method is simpler than the use of sulphuric and nitric acids r solution, but careful watching is required during the process of sion to avoid loss.

I give the following results of analyses of speise:

	I.	II.	III.
Separation by sodic sulphide,	17.2	12.3	7.95 per cent. Cu.
" " method A,	17.0	12.1	7.80 " " "
" " " B,	16.9	12.2	— " " "

From another sample of speise I obtained results as follows: ethod A, evaporation continued forty-five minutes after the appear- ce of sulphuric acid fumes—5.7 per cent. Cu. Method A, evapora- n continued but a few minutes after sulphuric acid fumes were first ven off—5.1 per cent. Cu. By evaporation with hydrochloric instead sulphuric acid, 5.2 per cent. Cu was obtained. In the last two amples the arsenic was not completely removed and titration s made as closely as possible to the appearance of the characteris- color due to arsenic.

NOTES ON THE ASSAY SPITZLUTTE,

FROM THE MINING LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BY ROBERT H. RICHARDS, S.B., PROFESSOR OF MINING.

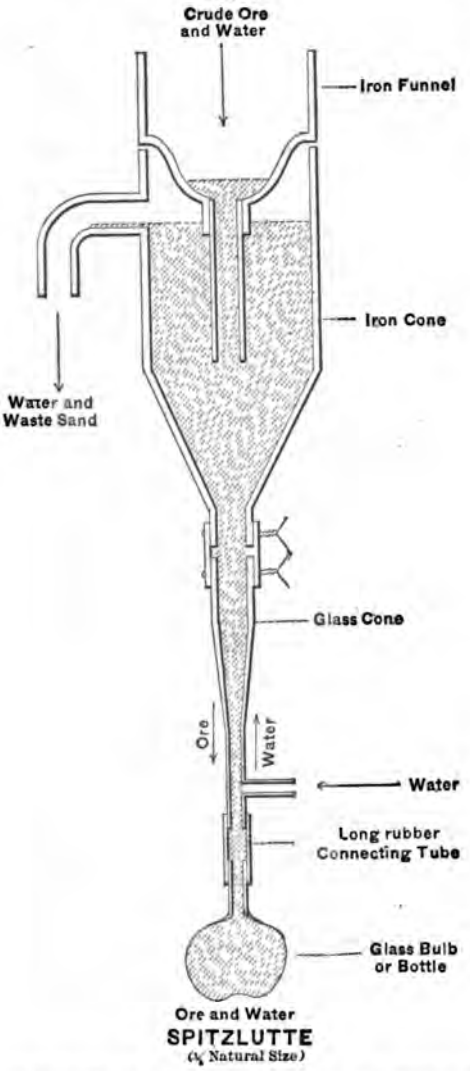
THE spitzlutte, as described by Rittinger, is an instrument which sand is sorted in a continual upward-flowing stream of wat Its usual form is that of a pointed box, placed with the point dow ward, the box receiving its feed of sand and water on one side a discharging its tailings on the other. The sorted product or co centration is discharged at the bottom, at the apex of the bo through which it falls against an upward current of water, whi current serves to effect the sorting and separation. To make t exposure to the quicksand condition still more effective, an invert dam is placed across the spitzlutte, which forces the sand in its p sage from the feed side to the discharge to pass down into the m active portion of the upward-flowing current of water.

In the form adopted for small tests in the mining laboratory the Massachusetts Institute of Technology (see accompanying sket the feed is through a central funnel instead of being at the side, a the apex of this funnel, extending down nearly to the apex of cone, takes the place of the inverted dam in the large spitzlu To keep the experiment perfectly under control a bulb or bottle attached by a rubber connecting-tube to receive the concentratio and between this bottle and the apex of the spitzlutte is place glass tube of conical form, with a side tube for the admission water. By regulating the admission of water through this tube concentration may be allowed to go down into the bulb as fast o slowly as the richness of the ore seems to demand.

This spitzlutte may be used on products that have been previou sized to take out the heavy mineral. As an example of this a was made upon a sample of ore where the galena, blende, and qua were much mixed up, but separated fairly when crushed. T sample of ore was from Newburyport, and assayed 16.50 per c lead. After sizing through a series of sieves the ore yielded conc trations and tailings to the spitzlutte as follows:

hrough. On.	Concentrations, Lead.	Middlings, Lead.	Tailings, Lead.
12 — 20	47.28 per cent.	11.38 per cent.	2.48 per cent.
20 — 30	47.81 "		1.67 "
30 — 40	48.61 "		2.56 "
40 — 50	51.93 "		3.54 "
50 — 90	50.95 "		1.18 "
90 —	31.93 "		Not worked

FIG. 1.



SPITZLUTTE
(¼ Natural Size)

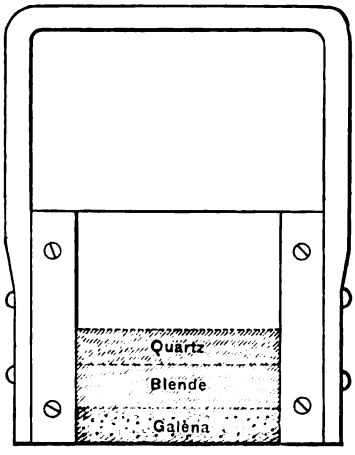
Again, this spitzlutte can be used on natural products. By these nean products that have been crushed simply without being subted to the usual process of sizing by a series of sieves. In this

case its overflow sand must be re-treated by the miners' pan or sich
ertrog to extract the finer portion of the ore. It makes a very goo
preliminary to the miners' pan, taking out the largest grains, whic
interfere with the pan's best action, leaving the finer grains of or
for the pan to finish.

The spitzlutte has been used by us mainly to separate mercur
and amalgam from pulp after amalgamating tests. For this purpos
it is very efficient. It is also used to gain an approximate idea
how an ore will concentrate, and how fine it should be crushed i
order to concentrate it to the best advantage on the large scale.

The little jig (shown in the accompanying sketch) used by us

FIG. 2.



JIG WITH GLASS SIDES
(½Natural Size)

a lecture experiment and as a test of larger machines is 6 inch
deep, 4 inches long, and 3 inches wide, with plate glass side
wooden ends, and a sieve bottom of 30 meshes to the inch.

This jig will show very perfect lines of separation between quart
specific gravity 2.6; blende, specific gravity 4; and galena, specif
gravity 7.5. It will show a partial separation between blende, sp
cific gravity 4; and magnetite, specific gravity 5.1.

The separation of red marble, white barite, and blue galena
very marked, and makes a good lecture experiment.

In using this jig to test the running of larger machines it simp
shows with what ease or difficulty a given set of layers may be ob
tained.

*E WEARING CAPACITY OF STEEL RAILS IN RELATION TO THEIR CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES.**

CHARLES B. DUDLEY, PH.D., CHEMIST, PENNSYLVANIA RAILROAD COMPANY, ALTOONA, PA.

EO. N. ELY, ESQ.,
Superintendent of Motive Power.

DEAR SIR: It is now nearly three years since my first report to on the subject of steel rails was written. That report, as you l remember, dealt principally with the question of the relation ween the chemical composition and physical properties of steel s and their power to resist crushing and fracture in actual service. ier matters were referred to or touched upon in that report, but main question was, Why do some rails crush or break in service ile others do not? You will doubtless remember that the princi- conclusion arrived at was, that the softer rails are less liable to sh or break in service than the hard ones. Or, in other words, far as conclusions could be drawn from the chemical analysis physical test of 25 samples of steel rails which had actually n in service, these conclusions were that those rails which have smaller amounts of carbon, phosphorus, silicon, and manganese less liable to crush or break in service than those which have ger amounts of these elements. Or, again, looked at in the light

* At the Lake George meeting of the Institute in October, 1878, I had the r of presenting to the Institute, through the kind permission of the officers he Pennsylvania Railroad Company, the results of a study of twenty-five les of steel rails, which had all been in actual service. Considerable dis- ion followed the publication of that paper, and there seemed to be a strong clination, especially on the part of the steel-rail manufacturers, to accept the lusions presented. One of the principal objections urged against the conclu- drawn was, that they were based on too few samples; in other words, that no lusions safe to act upon could be drawn from the examination of twenty-five In view of this criticism it was decided to repeat the investigation with ger number of samples, and with the aid of the experience gained in the investigation. The results of this second study of steel rails are, by the ission of the officers of the Pennsylvania Railroad Company, herewith nted to the Institute, with the sincere desire that they may aid in adding r knowledge of this most important product. Like the previous paper, this the form of a report to one of the officers of the company, which will nt for the style, and the manner of presenting the data

of physical tests, those rails which have the lower tensile streng
and the greater elongation are the ones which give the least troub
from breaking or crushing in track.

In the report just referred to, the question of the wearing capaci
of steel rails was not made prominent, and from that report no positiv
and definite information could be obtained as to what quality of ste
would give rails that would endure the greatest amount of traff
with the least loss of metal. And yet, of the three principal caus
which occasion the removal of rails from the track, viz., breakin
crushing, and wearing out, perhaps the latter is of the most importanc
With the improvement in maintenance of way which has characte
ized the Pennsylvania Railroad during the last five or six yea
the removal of rails from track from the first two of these caus
has, if I am right, notably diminished. This certainly is true wi
regard to broken rails. And if, as time advances, the number
crushed rails shall diminish, both because of the continued in
provement in maintenance of way, before referred to, and becaus
owing to improved and better methods at the steel works, there a
fewer crushed rails caused by physical defects in the steel, the questi
of the wearing capacity of steel rails obviously becomes the a
important one. In view of these considerations, it was thoug
that an investigation into the relation between the wear of ste
rails and their chemical composition and physical properties cou
not fail to throw light upon a question of vital importance in t
management of the Pennsylvania Railroad. The results of such
investigation are presented in the following report, which deals, n
as did the previous report, with the relations between the chemic
and physical characteristics of steel rails and their power to res
crushing or fracture, but entirely with the relation between the
characteristics and wear.

On any railroad the rails are or may be called upon to perfo
their service under varying conditions.. On a railroad like t
Pennsylvania Railroad, for example, there are levels and grad
and there are tangents and curves, and there are combinations of t
levels and grades with the tangents and curves. Moreover, the ra
on the high sides of curves do their service under different con
tions from those on the low sides of curves. So that, as far
kind of service is concerned, a rail may be called upon to do
work under one of these six conditions, viz., on level tangent,
high side of level curve, on low side of level curve, on grade ta
gent, on high side of grade curve, or on low side of grade curv

ny investigation, therefore, into the wearing capacity of steel rails, hich shall be of service in determining what rails are best for e whole road, must take into account these six conditions. Of urse there are many different grades and curves of different radius the Pennsylvania Railroad; but to study wear on each grade, d for every radius of curvature, would make a problem almost life-ng. In order, therefore, to make the work manageable it becomes cessary to choose some average grade and some medium degree of rvature, as representing the different grades and curves on the ad. This has been done in the work about to be described.

Now, the problem before us is: What chemical composition and hat physical properties are characteristic of those rails which in tual service have lost least metal in proportion to the tonnage that has ssed over them? In order to get the information necessary to answer is question, 64 rails were taken from the track in July, 1879, and bjected to chemical analysis and physical test, as is detailed further . Sixteen of these rails were taken from level tangents and 16 om level curves, 8 from the high side and 8 from the low side of the rves. Again, 16 rails were taken from grade tangents and 16 from ade curves, 8 from the high side and 8 from the low side of these rves. The 32 rails on grades were all taken between Conemaugh d Altoona, and the 32 on levels between Tyrone and Mifflin. rthermore, 32 of the rails were taken from the north track, and from the south track. The principle governing the selection was secure 8 as slow-wearing rails and 8 as rapid-wearing rails as could found on each of the four conditions of service,—level tangents, vel curves, grade tangents, and grade curves,—the rails on curves ing taken, as has been already described, one-half from the high le of the curve and one-half from the low side of the curve. In e actual selection a pair of callipers was used, and the loss in height a rail, compared with its time of service, gave a sufficiently accu-te measure of the rate of wear of a rail to determine its selec-n. It should be stated here that since the rails were selected in ly, after the usual annual removal from the track of worn-out ls, which takes place earlier in the season, the more rapid-wearing ls obtained for examination are not as marked examples of rapid-aring rails as would have been obtained had the selection been lier made. With regard to the 64 rails chosen, it may also be ted that not one of them had broken in service, and only one owed any signs of crushing; so that, as far as every quality is ncerned, except their rate of wear, all of them might be classed as od rails.

It was thought that a chemical examination and physical te of the 64 rails, compared with the loss of metal they had su fered by the tonnage which had passed over them, could not fail throw some light on the question as to what kind of steel in ra gives best wear. These rails having been selected were remov from the track and sent to Altoona. They were then cleaned a weighed on an ordinary platform scale, their length measured as a curately as possible with a steel-tape, and their height calliper near both ends and in the middle. The weight of the whole r divided by its length obviously gives the present weight per yard these worn rails. The weights obtained in this manner, howev were not subsequently used, as will be explained further on. Af the weighing, five feet were cut off from the end of each rail for te purposes. The test-pieces, except those used in the bending te were all cut from the head of the rail. Two pieces for tensile te two for torsion test, and two pieces from the web for bending te as well as a section of the rail $\frac{1}{2}$ inch thick, were taken from ea rail. The tensile test-pieces were 15 inches long, with a reduc section $\frac{3}{4}$ inch in diameter, and 5 inches between shoulders. Th also had a groove just beyond each end of the reduced section f holding the micrometer arrangement used in determining the elas limit. The torsion test-pieces were of the usual size, 4 inches lo and 1 inch square, with a reduced section $\frac{5}{8}$ inch in diameter, and inch between shoulders, with a $\frac{1}{8}$ inch fillet. For the shearing t one-half of the tensile test-pieces, after they were broken, was turn down to a rod $\frac{5}{8}$ inch in diameter, and sheared off (single shear) in shearing apparatus prepared for the purpose. For the bending t two pieces $1\frac{1}{2}$ inch wide, and 12 inches long, were slotted out of t web of each rail. Accompanying Plate 1 gives the details of t form and size of the test-pieces and of the shearing apparat A and B represent the shearing apparatus, full size; C represe the tensile test-piece, half size; D, the torsion piece, full size; the shearing piece, full size; and F, the bending test-piece, half si The half-inch section of each rail was used in determining the pr ent weight per yard of the worn rails, the original weight per ya of these rails when laid, as will be described further on, and a in making the diagrams of the worn rails, which appear in the companying Plates 2, 3, 4, and 5.

When the tensile test-pieces had been prepared, one-half of th were annealed by heating them to a fair red heat, and then allowi them to cool slowly for 36 hours. Both the annealed and the una nealed test-pieces were then tested in the tensile testing-machi

determining the elastic limit yokes were fitted to the grooves in
e test-pieces prepared for them, which yokes carried micrometer
ews on opposite sides of the pieces, reading to the ten thousandth
an inch, and fitted up for electrical contact. The pieces were
en strained with successive loads, increasing by 2000 pounds per
uare inch. After the application of each load the elongation
s measured by the micrometers, and the point at which the elon-
tion ceased to be directly proportioned to the load was regarded as
e elastic limit. The results of these tests are given on Plates
nd 7. The figures as to tensile strength and elastic limit mean
unds per square inch. The elongation is per cent. in five inches.
ither of the torsion test-pieces were annealed, they being tested in
e condition in which the steel was when removed from the track.
e diagrams made by the test of these pieces were measured up,
d the results are given in connection with the results of the ten-
e tests as above described. The figures given as to length of dia-
am, height of diagram, and elastic limit are in inches and hun-
edths of an inch; and those giving areas of diagram are square
hes. They are the mean of the results from the two test-pieces.
the shearing tests the figures given under "shearing stress" are
unds per square inch; while the "detrusion" before rupture repre-
nts the travel or motion of the shearing piece A, in Plate 1,
easured in decimals of an inch. In making these measurements
oad of 2000 pounds was put on the pieces and then a reading
de; at the moment of rupture another reading was made. The
ference of these two readings represents the detrusion. In
king the bending tests, the pieces before described were supported
knife-edges 10 inches apart, and bent by a third knife-edge at
ual distances from the supports, after the manner of making trans-
rse tests of metal. In making these tests it was found that the
d applied gradually increased until it reached a maximum, and
en diminished slowly. The deflection obtained at the point of
ximum load varied considerably in the different rails, being a
f inch or more each side of two inches. After the maximum
d had been obtained as above described, the pieces were removed
m the strain, and set up on end in the same machine, and
n bent until rupture took place or until they could be bent down
farther. The broken or bent pieces were then laid on a piece of
per in the position in which they were at rupture or as bent, and
amount of deflection from a straight line of the piece broken
bent was measured with a protractor. The figures given under
head "bending tests" are maximum load and deflection. The

maximum load was calculated from the data obtained in testing pieces, for a piece 1½ inch wide and ½ inch thick. The deflectio in degrees. In all cases where the deflection is given as 190°, pieces did not break, but had the form when removed from machine of a letter U with the ends brought together until t formed with each other an angle of 10°.

From the torsion test-pieces after they were broken borings w taken for analysis In these borings the carbon, phosphorus, silic and manganese were determined. All the chemical work was d in duplicate. The carbon was determined, after separation from iron by chloride of copper and ammonium, by combustion in oxy gas, the phosphorus by the molybdate method, the manganese by bromine method, and the silicon in the usual manner. The res of these determinations are given with the other data. So much the methods of the chemical and physical testing of these rails.

In determining the rate of wear of a steel rail it is of co necessary to know the loss of metal per yard which each rail suffered and the tonnage. The loss of metal per yard divided the tonnage gives the rate of wear; and when these data are obtai for a series of rails, they furnish a means of comparison as to t wearing capacity.

The tonnage of the 64 rails we are studying was computed f the data as to number of trains and movement of cars in the o of the superintendent of transportation, Mr. John Reilly. T data were twice worked over, and while I do not think that the t nages given with each rail are absolutely the number of tons w have passed over them, I do think that the percentage erro small, and that the comparison of one rail with another by mean these tonnages, which is really what we are after, gives results t can safely be relied on.

With regard to the loss of metal per yard and the method which it was obtained it will be necessary to go a little into de Of course nothing could be simpler than to obtain the loss of m per yard of these rails provided the data were at hand, for thi simply the difference between the present weight per yard of worn rails and the original weight per yard of these rails when t were laid. But unfortunately these rails were not weighed w they were put in track, and so one essential element of our dat wanting. Nor will it do to assume that these rails origin weighed 67 lbs. or 56 lbs. per yard, which is the standard weigh the different rails embraced in this series. Mr. J. W. Cloud, e neer of tests, finds by the weight of a number of new rails

om the mills, weighed at Altoona during two or three years past, at they vary from ½ lb. to 1½ lb. per yard from standard weight. till further, an examination of the rails in our series shows that ome of them, from the web being thinner than standard, which eans that the rolls were closer together when that rail was rolled, ould not have weighed when new more than 64 lbs. or 65 lbs. per ard.

In view of these statements, the question fairly meets us: How can he loss of metal per yard of these rails be determined? It is evident to all, I think, that if we know the weight per yard of these orn rails, and then are able to obtain the areas (1) of a section of he worn rail, and (2) of a section of the original rail as rolled, we ave at hand all the data necessary for obtaining the weight per ard of the rail as rolled. For it is clear, I am sure, that as the rea of a section of the worn rail is to its weight per yard so is the area f a section of the original rail to its weight per yard. If, therefore, e can obtain (1) the weight per yard of the worn rails, (2) the area f a section of each of these rails, and (3) the area of a section of each ail as rolled, we shall be able to obtain the loss of metal per yard f each of the rails in the series we are studying. Can these data hen be obtained?

First, as to the areas. How can the area of a section of the worn ail and of a section of the rail as rolled be obtained? The following was the method used. The half-inch section of the worn rails before referred to was laid upon a sheet of paper, and its outline traced pon the paper with the utmost care by means of a very sharp-ointed hard pencil. The surface inclosed within this tracing corresponds very closely with the section of the worn rail. Then directly over this tracing was laid the template of the section after which his rail was rolled, and a tracing then made with a sharp-pointed ard pencil as before of that portion of the head which was lacking n the worn rail. If now the original height of the rail was the ame as the template used, and if the original shape of the head f the rail was that of the template, we have in this manner a iagram on paper representing a section of the worn rail, and so one representing a section of the original rail as rolled. The iagrams obtained in this manner for each rail in the series are epresented in accompanying Plates 2, 3, 4, and 5. The areas of hese diagrams were then obtained by means of the planimeter.

What now are the assumptions, and what are the probable errors n this method? The first assumption is that the original rails as

rolled were of the same height as the template. This is probabl not exactly true in fact. The wear of the rolls, and possib carelessness in making the rolls originally, together with the fa that the rails rolled in the same set of rolls were probably n all rolled at the same temperature, and consequently shrunk l different amounts in cooling, might occasion small deviatio from the height which the rail should have according to templat And yet Mr. Cloud, engineer of tests, has callipered the height some 60 new rails here at Altoona during the year past, which rai were from different mills, and has found the variation from stan ard height not more than $\frac{1}{100}$ of an inch. It would seem, ther fore, that the error arising from the assumption as to height of ra could not be large.

The second assumption is that the original shape of the top the head of the rails we are studying was that of the templat This is of course a question of accuracy in the original manufactu of the rolls, and of their wear. Now it is impossible to say ho accurately the rolls were originally made, and how much they hav worn out of shape when any rail was rolled. But in any case th error must be very small, for any noteworthy deviation of the to of the head from standard would have given difficulty in securing straight, even track, and would have caused the rejection of tho rails by the inspector at the mills.

The third assumption is that these rails have not suffered disto tion as to height by the service which they have endured. Upo this point I will say that I think an inspection of the diagrams i accompanying Plates 2, 3, 4, and 5 will convince any one th this distortion, if any, is excessively small. It should be state here that any deviation of these rails from template, such as beadin over on one side of the head, or thicker or thinner webs tha standard, or variation in the shape of the foot or in the under sid of the head, can cause no error, because in taking the areas with th planimeter, the diagrams from which the area of the worn sectio and the area of the original section were taken, coincide in ever part except in that part of the original section which was traced-i from template as above described. In other words, in getting th areas of the rails as rolled, the actual section of the rail just as was rolled was used in every part, except that portion of the hea which was gone from wear, which portion was restored fro template.

Again, how accurately can the areas be obtained by means

he planimeter? The planimeter which was used gave readings to $\frac{1}{100}$ of a square inch. If, therefore, the manipulation was such as o give the instrument its full chance, the maximum error in area ould not be over $\frac{1}{100}$ of a square inch. As a matter of fact, in aking the areas with the planimeter, from three to five measure- nents were made of each diagram, which measurements differed rom each other not more than from one to three hundredths of an nch, and then a mean of these measurements was taken as repre- enting the area of the diagram. It seems probable, therefore, that he error arising from this cause could not in any case amount to nore than one or two hundredths of a square inch.

Now as to the weight per yard of the worn rails. How can this best be obtained? Obviously the most simple method would be to veigh each of the worn rails, and then divide the weight by the ength. This was done with these rails, as has already been men- ioned. But when the results were obtained, and the original veight of the rails computed, by means of the areas as above lescribed, it was found that some rails rolled at the same mill, at he same time, and with the same thickness of web and same shape f foot, differed from each other in the original weight, as computed, rom $1\frac{1}{2}$ to 3 lbs. per yard. The explanation of this seems to be hat the half-inch sections before referred to, which were used in getting the areas, did not exactly represent the whole rail; in other words, the rail was unevenly worn. This explanation was con- irmed by callipering the height of the half-inch sections, and com- paring these heights with the heights of the rail in different places. t became necessary, therefore, to devise some other means of ob- aining the weight per yard of the worn rails, and it was finally lecided to obtain the desired weights from the half-inch sections hemselves before referred to. These sections were all, therefore, arefully weighed on a balance which weighed accurately to one-half grain. If, now, the half-inch sections were exactly half an inch n thickness, a little consideration shows that it is possible in this vay to get at the weight of a rail more accurately than it could be btained by weighing the whole rail on a common platform scale, upposing, of course, that the rail was uniform in section throughout s length. For there are 72 half-inch sections in a yard, and in a 0-foot rail 720 half-inch sections. If, now, the error in weighing half-inch section is one-half a grain, the total error in the weight f a 30-foot rail would be 720 half grains, or 360 grains, which is little less than an ounce. Inasmuch, therefore, as ordinary plat-

form scales do not generally weigh closer than half a pound, it i evident that, so far as accuracy of weighing is concerned, the metho of getting at the weight per yard of these worn rails, by weighin the half-inch sections, leaves nothing to be desired.

But were these half-inch sections exactly half an inch thick An examination of these sections by means of vernier callipers reading to one-thousandth of an inch, showed that they were not ex actly half an inch thick, and that they varied in thickness in differ ent parts of the section. The reasons for this seem to be, that it almost impossible to set a tool so as to cut off exactly half an inc from a rail, and that in cutting steel as hard as some of these rai were, the tool is apt to spring more or less, and thus give a sectio of varying thickness. It became necessary, therefore, to devise som method by means of which the average thickness of these section could be obtained. This was done as follows: The half-inch sec tions were all carefully weighed in distilled water, at a temperatur of 66° F., on a balance weighing to half a grain. The differenc between the weight so obtained and the weight of the same section in air gives the weight of a volume of water equal to the volume o the section. Now, this weight of water divided by the weight of cubic inch of water, which was taken as 252.5 grains, gives the vo ume or space occupied by any section. This volume being known it is of course only necessary to divide the same by the area obtaine by the planimeter, as before described, and the result is the averag thickness of each section; and the weight and thickness of eac section being known, a very simple calculation gives us the weigh per yard, corresponding to each of the worn rails which we ar dealing with.

Now, what are the possible errors involved in this method? A to the weight in air of the half-inch sections, it has already bee shown that an error of half a grain in the weight of each sectio gives an error per yard that can safely be ignored. An error half a grain in weighing the sections in water gives an error in th weight per yard of the worn rail of .05 of a pound; and an error a hundredth of a square inch in taking the areas of the sections wit the planimeter causes an error in the weights of about a tenth of pound. It seems fair, therefore, to conclude that probably th weights of the worn rails and of these rails when originally laid, obtained in the manner above described, do not differ from the tru weights more than possibly a quarter of a pound per yard.

It is, of course, to be confessed that whatever errors the

may be, either in the weight of the worn rails or in the original weight of these same rails, appears in the loss of metal due to wear, —which is really what we are after,—and which is simply the difference between these two weights. But it must be remembered that, in determining the value of a rail, this loss of metal is subsequently divided by the tonnage, and consequently the influence of the error is thereby very greatly diminished. And while there may be a few rails in the series which occupy a place which they would not occupy if the loss of metal were more accurately known, yet I think these cases are too few to seriously obscure or counteract the general conclusions which the results that have been obtained are calculated to teach.

In the following pages are given the history of each rail and the tonnage. The essential parts of this history, together with the tonnage, the chemical analyses, the weights per yard, and loss of metal, as well as the loss per million tons, and the complete results of the physical tests and the density, are given in tabular form in accompanying Plates 6 and 7. These tables will be discussed farther on. The density is the weight of a cubic inch of the steel. This weight was obtained by dividing the weight of each of the half-inch sections by its volume, the data for this purpose having been obtained as previously described. The figures given under density are fractions of a pound.

In looking over the original weights of the rails as obtained, it will doubtless be observed, that although these rails were all supposed to have weighed 67 lbs. or 56 lbs. per yard when rolled, the figures given differ both ways from these figures. These differences are principally to be accounted for by differences in the shape of the bases and differences in the thickness of the webs. With regard to the latter point, it is evident that of two rails rolled at the same mill, in the same year, if one has a web three or five one-hundredths of an inch thicker than another,—which means that the rolls were farther apart when the thick-web rail was rolled,—the thin-web rail will be lighter than the other. The thickness of the webs of all the rails in the series we are studying was carefully measured with vernier calipers, and the differences from the standard thickness were found to vary both ways, from nothing up to five one-hundredths of an inch thinner than standard, and seven one-hundredths thicker than standard. Finally, the differences in the density of the different rails still further help us to account for the differences in weight per yard of the rails as rolled.

The following is the history and tonnage of the different rails:

No. 881. Steel of 1868. Was on tangent, north rail, north track in Bennington Cut. In service from June, 1868, to July, 187 —11 yrs. 1 mo. Grade, 92.4 ft. to the mile. Tonnage, 55,546,81 tons.

No. 882. Steel of 1868. Was on tangent, north rail, north track in Bennington Cut. In service from June, 1868, to July, 1879— 11 yrs. 1 mo. Grade, 92.4 ft. to the mile. Tonnage, 55,546,81 tons.

No. 883. Steel of 1869. Was on tangent, north rail, north track on Whip-poor-will Straight. In service from May, 1869, to July 1879—10 yrs. 2 mos. Grade, 95.04 ft. to the mile. Tonnage 52,174,969 tons.

No. 884. Steel of 1869. Was on tangent, north rail, north track on Whip-poor-will Straight. In service from May, 1869, to July 1879—10 yrs. 2 mos. Grade, 95.04 ft. to the mile. Tonnage 52,174,969 tons.

No. 885. Steel of 1868. Was on tangent, south rail, north track, just west of Allegrippus Station. In service from July, 1868 to July, 1879—11 yrs. Grade, 89.76 ft. to the mile. Tonnage 55,197,994 tons.

No. 886. Steel of 1868. Was on tangent, north rail, north track, just west of Allegrippus Station. In service from July, 1868 to July, 1879—11 yrs. Grade, 89.76 ft. to the mile. Tonnage 55,197,994 tons.

No. 887. Steel of 1868. Was on tangent, south rail, north track, west of Allegrippus Station. In service from July, 1868 to July, 1879—11 yrs. Grade, 89.76 ft. to the mile. Tonnage 55,197,994 tons.

No. 888. Steel of 1868. Was on tangent, south rail, north track, west of Allegrippus Station. In service from July, 1868 to July, 1879—11 years. Grade, 89.76 ft. to the mile. Tonnage 55,197,994 tons.

No. 889. Steel of 1873. Was on tangent, south rail, south track, at South Fork. In service from August, 1873, to July 1879—5 yrs. 11 mos. Grade, 21.13 ft. to the mile. Tonnage 44,620,100 tons.

No. 890. Steel of 1873. Was on tangent, north rail, south track, at South Fork. In service from August, 1873, to July 1879—5 yrs. 11 mos. Grade, 21.13 ft. to the mile. Tonnage 44,620,100 tons.

No. 891. Steel of 1872. Was on tangent, south rail, south rack, at Summer Hill water plug. In service from June, 1872, o July, 1879—7 yrs. 1 mo. Grade, 40.13 ft. to the mile. Tonnage, 53,687,192 tons.

No. 892. Steel of 1872. Was on tangent, south rail, south rack, at Summer Hill water plug. In service from June, 1872, o July, 1879—7 yrs. 1 mo. Grade, 40.13 ft. to the mile. Tonnage, 53,687,192 tons.

No. 893. Steel of 1874. Was on tangent, north rail, south rack, near Summer Hill. In service from May, 1874, to July, 879—5 yrs. 2 mos. Grade, 21.12 ft. to the mile. Tonnage, 8,088,572 tons.

No. 894. Steel of 1874. Was on tangent, south rail, south track, ast of Portage. In service from May, 1874, to July, 1879—5 rs. 2 mos. Grade, 52.8 ft. to the mile. Tonnage, 38,088,572 ons.

No. 895. Steel of 1874. Was on tangent, south rail, south track, ast of Portage. In service from May, 1874, to July, 1879—5 rs. 2 mos. Grade, 52.8 ft. to the mile. Tonnage, 38,088,572 ons.

No. 896. Steel of 1874. Was on tangent, south rail, south track, ast of Portage. In service from May, 1874, to July, 1879—5 rs. 2 mos. Grade, 52.8 ft. to the mile. Tonnage, 38,088,572 ons.

No. 897. Steel of 1868. Was on high side of 5° curve, north ail, north track, east of Bridge No. 3, Summer Hill. In service rom May, 1868, to July, 1879—11 yrs. 2 mos. Grade, 21.12 ft. o the mile. Tonnage, 52,370,617 tons.

No. 898. Steel of 1868. Was on high side of 5° curve, north ail, north track, east of Bridge No. 3, Summer Hill. In service om May, 1868, to July, 1879—11 yrs. 2 mos. Grade, 21.12 ft. o the mile. Tonnage, 52,370,617 tons.

No. 899. Steel of 1868. Was on low side of 5° curve, south ail, north track, east of Bridge No. 3, Summer Hill. In service om May, 1868, to July, 1879—11 yrs. 2 mos. Grade, 21.12 ft. the mile. Tonnage, 52,370,617 tons.

No. 900. Steel of 1868. Was on low side of 5° curve, north ail, north track, east of Bridge No. 3, Summer Hill. In service om May, 1868, to July, 1879—11 yrs. 2 mos. Grade, 21.12 ft. the mile. Tonnage, 52,370,617 tons.

No. 901. Steel of 1871. Was on low side of 5° curve, south rail, north track, in Gable's Cut, near Summer Hill. In service from August, 1871, to July, 1879—7 yrs. 11 mos. Grade, 39.6 ft. to the mile. Tonnage, 40,061,230 tons.

No. 902. Steel of 1871. Was on high side of 5° curve, north rail, north track, in Gable's Cut, near Summer Hill. In service from August, 1871, to July, 1879—7 yrs. 11 mos. Grade, 39.6 ft. to the mile. Tonnage, 40,061,230 tons.

No. 903. Steel of 1876. Was on high side of 5° curve, south rail, south track, west of Bridge No. 1, Summer Hill. In service from August, 1876, to July, 1879—2 yrs. 11 mos. Grade, 39.6 ft to the mile. Tonnage, 21,504,824 tons.

No. 904. Steel of 1876. Was on low side of 5° curve, north rail, south track, west of Bridge No. 1, near Summer Hill. In service from August, 1876, to July, 1879—2 yrs. 11 mos. Grade 39.6 ft. to the mile. Tonnage, 21,504,824 tons.

No. 905. Steel of 1868. Was on high side of 5° curve, north rail, north track, east end of Wilmore Middle Siding. In service from June, 1868, to April, 1879—10 yrs. 10 mos. Grade, 47.52 ft. to the mile. Tonnage, 50,648,939 tons.

No. 906. Steel of 1868. Was on low side of 5° curve, south rail, north track, east end of Wilmore Middle Siding. In service from June, 1868, to April, 1879—10 yrs. 10 mos. Grade, 47.52 ft. to the mile. Tonnage, 50,648,939 tons.

No. 907. Steel of 1874. Was on high side of 5° curve, north rail, north track, east of Wilmore Middle Siding. In service from June, 1874, to April, 1879—4 yrs. 10 mos. Grade, 47.52 ft. to the mile. Tonnage, 24,211,147 tons.

No. 908. Steel of 1875. Was on low side of 4° curve, north rail, south track, near tower at east end of Galitzin Tunnel. In service from May, 1875, to July, 1879—4 yrs. 2 mos. Grade 95.04 ft. to the mile. Tonnage, 32,428,614 tons.

No. 909. Steel of 1875. Was on high side of 4° curve, south rail, south track, near tower at east end of Galitzin Tunnel. In service from May, 1875, to July, 1879—4 yrs. 2 mos. Grade 95.04 ft. to the mile. Tonnage, 32,428,614 tons.

No. 910. Steel of 1871. Was on low side of 5° curve, south rail, south track, west of Allegrippus Station. In service from July, 1871, to July, 1879—8 yrs. Grade, 89.76 ft. to the mile. Tonnage, 62,813,664 tons.

No. 911. Steel of 1877. Was on low side of 5° curve, south l, south track, second curve west of Allegrippus Tower. In ser-ce from April, 1877, to July, 1879—2 yrs. 3 mos. Grade, 89.76 to the mile. Tonnage, 17,226,993 tons.

No. 912. Steel of 1873. Was on high side of 5° curve, north l, south track, second curve west of Allegrippus Tower. In ser-ce from July, 1873, to July, 1879—6 yrs. Grade, 89.76 ft. to e mile. Tonnage, 47,438,145 tons.

No. 913. Steel of 1870. Was on tangent, north rail, north track, 0 ft. west of mile-post 211 from Philadelphia. In service from arch, 1870, to July, 1879—9 yrs. 4 mos. On level. Tonnage, ,855,101 tons.

No. 914. Steel of 1870. Was on tangent, south rail, north track, 0 ft. west of mile-post 211 from Philadelphia. In service from arch, 1870, to July, 1879—9 yrs. 4 mos. On level. Tonnage, ,855,101 tons.

No. 915. Steel of 1873. Was on tangent, south rail, north ck, east of Petersburg Tool-house. In service from June, 1873, July, 1879—6 yrs. 1 mo. On level. Tonnage, 31,514,889 tons.

No. 916. Steel of 1873. Was on tangent, north rail, north track, t west of Ardenheim. In service from July, 1873, to July, 1879 6 yrs. On level. Tonnage, 31,127,829 tons.

No. 917. Steel of 1873. Was on tangent, south rail, north track, t west of Ardenheim. In service from July, 1873, to July, 1879 6 yrs. On level. Tonnage, 31,127,829 tons.

No. 918. Steel of 1869. Was on tangent, north rail, north track, st of Vandevaner's Bridge. In service from January, 1869, to ly, 1879—10 yrs. 6 mos. On level. Tonnage, 51,720,011 tons.

No. 919. Steel of 1869. Was on tangent, north rail, north track, st of Vandevaner's Bridge. In service from January, 1869, July, 1879—10 yrs. 6 mos. On level. Tonnage, 51,720,011 s.

No. 920. Steel of 1867. Was on tangent, south rail, north track, Jackstown Water-trough. In service from December, 1867, to ly, 1879—11 yrs. 7 mos. On level. Tonnage, 52,991,684 tons.

No. 921. Steel of 1874. Was on tangent, north rail, north track,) ft. east of mile-post 211 from Philadelphia. In service from rch, 1874, to July, 1879—5 yrs. 4 mos. On level. Tonnage, 622,230 tons.

No. 922. Steel of 1874. Was on tangent, south rail, north tra
200 ft. east of mile-post 211 from Philadelphia. In service fr
March, 1874, to July, 1879—5 yrs. 4 mos. On level. Tonna
27,622,230 tons.

No. 923. Steel of 1873. Was on tangent, south rail, north tra
east of Petersburg Tool-house. In service from June, 1873, to Ju
1879—6 yrs. 1 mo. On level. Tonnage, 31,514,889 tons.

No. 924. Steel of 1875. Was on tangent, south rail, south tra
west of Vandevaner's Bridge. In service from June, 1875, to Ju
1879—4 yrs. 1 mo. On level. Tonnage, 36,349,989 tons.

No. 925. Steel of 1875. Was on tangent, south rail, south tra
west of Vandevaner's Bridge. In service from June, 1875, to Ju
1879—4 yrs. 1 mo. On level. Tonnage, 36,349,989 tons.

No. 926. Steel of 1870. Was on tangent, south rail, south tra
1500 ft. west of mile-post 182 from Philadelphia. In service fr
April, 1870, to July, 1879—9 yrs. 3 mos. On level. Tonna
76,409,123 tons.

No. 927. Steel of 1870. Was on tangent, south rail, south tra
1500 ft. west of mile-post 182 from Philadelphia. In service fr
April, 1870, to July, 1879—9 yrs. 3 mos. On level. Tonna
76,409,123 tons.

No. 928. Steel of 1874. Was on tangent, south rail, south tra
200 ft. east of mile-post 181 from Philadelphia. In service fr
July, 1874, to July, 1879—5 years. On level. Tonnage, 43,610,1
tons.

No. 929. Steel of 1867. Was on high side of 2¼° curve, no
rail, north track, 250 ft. east of mile-post 194 from Philadelpl
In service from December, 1867, to July, 1879—11 yrs. 7 mos.
level. Tonnage, 52,991,684 tons.

No. 930. Steel of 1867. Was on low side of 2¼° curve, sou
rail, north track, 250 ft. east of mile-post 194 from Philadelpl
In service from December, 1867, to July, 1879—11 yrs. 7 mos.
level. Tonnage, 52,991,684 tons.

No. 931. Steel of 1868. Was on high side of 3° curve, sou
rail, north track, 400 ft. east of mile-post 191 from Philadelpl
In service from January, 1869, to July, 1879—10 yrs. 6 mos.
level. Tonnage, 51,720,011 tons.

No. 932. Steel of 1868. Was on low side of 3° curve, north r
north track, 400 feet east of mile-post 191 from Philadelphia.

vice from January, 1869, to July, 1879—10 yrs. 6 months. On el. Tonnage, 51,720,011 tons.

No. 933. Steel of 1869. Was on high side of 3½° curve, north , south track, 1000 feet east of mile-post 183 from Philadelphia. service from November, 1869, to July, 1879—9 yrs. 8 mos. On el. Tonnage, 78,364,968 tons.

No 934. Steel of 1869. Was on low side of 3½° curve, south rail, th track, 1000 feet east of mile-post 183 from Philadelphia. In vice from November, 1869, to July, 1879—9 yrs. 8 mos. On el. Tonnage, 78,364,968 tons.

No. 935. Steel of 1866. Was on high side of 2° curve, north , south track, at McVeytown Station. In service from Sep- ber, 1866, to June, 1879—12 yrs. 9 mos. On level. Tonnage, 025,478 tons.

No. 936. Steel of 1866. Was on low side of 2° curve, south , south track, at McVeytown Station. In service from Sep- ber, 1866, to June, 1879—12 yrs. 9 mos. On level. Tonnage, 025,478 tons.

No. 937. Steel of 1876. Was on low side of 2° curve, south rail, th track, 200 ft. west of mile-post 192 from Philadelphia. In vice from March, 1876, to July, 1879—3 yrs. 4 mos. On level. nnage, 29,905,122 tons.

No. 938. Steel of 1876. Was on high side of 2° curve, north rail, th track, 200 ft. west of mile-post 192 from Philadelphia. In vice from March, 1876, to July, 1879—3 yrs. 4 mos. On level. nnage, 29,905,122 tons.

No. 939. Steel of 1875. Was on the low side of 4° curve, south , south track, 250 ft. east of Mount Union Bridge. In service n May, 1875, to July, 1879—4 yrs. 2 mos. On level. Tonnage, 150,179 tons.

No. 940. Steel of 1875. Was on the high side of 4° curve, north , south track, 250 ft. east of Mount Union Bridge. In service n May, 1875, to July, 1879—4 yrs. 2 mos. On level. Tonnage, 150,179 tons.

No. 941. Steel of 1874. Was on high side of 3° curve, south , south track, 300 ft. east of Manayunk. In service from Sep- ber, 1874, to July, 1879—4 yrs. 10 mos. On level. Tonnage, 277,638 tons.

No. 942. Steel of 1874. Was on low side of 3° curve, north rail, th track, 300 ft. east of Manayunk. In service from September,

1874, to July, 1879—4 yrs. 10 mos. On level. Tonnage, 42,277 tons.

No. 943. Steel of 1873. Was on the low side of 2° curve, s rail, south track, 2000 ft. west of mile-post 179 from Philadel In service from April, 1873, to July, 1879—6 yrs. 3 mos. On l Tonnage, 55,127,464 tons.

No. 944. Steel of 1873. Was on high side of 2° curve, n rail, south track, 2000 ft. west of mile-post 179 from Philadel In service from April, 1873, to July, 1879—6 yrs. 3 mos. On l Tonnage, 55,127,464 tons.

Accompanying Plates 6 and 7 give in tabular form all the e tial data of the history of the rails, together with the che analyses, weights, and results of the physical tests, as has been b stated. To a study of these tables attention is now directed. will be observed, the rails have been arranged in six groups, ac ing to the kind of service to which they have been subjected. first group of 16 rails did their service on grade tangents; the se group of 8 rails on the low side of grade curves; the third grou 8 rails on the high side of grade curves; the fourth group of 16 on level tangents; the fifth group of 8 rails on the low side of curves; and the sixth group of 8 rails on the high side of curves. As will likewise be observed, the rails within the gr have been arranged in regular order according to loss of meta million tons, the rail having lost least metal per million tons b placed first. The first rails in the several groups are therefor slower wearing, while the latter rails are the more rapid wea This arrangement enables us to compare the slower-wearing ra the different kinds of service with the more rapid-wearing ones, to discover what physical qualities, and what chemical composi are characteristic of the slower-wearing as well as the faster-we rails.

Giving our attention now to the tables, I think the first obs tion will be that there is no absolute gradation in physical qual or in chemical composition, applying to every rail in each g which corresponds to the gradation in amount of metal lost per mi tons. In other words, if we take tensile strength, or elongation i physical qualities, or the carbon or phosphorus in the chemical position, we do not find that the first rail in each group is chara ized by a certain figure in any one or more of these respects, whil last rail in the group is characterized by another different figure all the intermediate rails arrange themselves in respect to a

hese peculiarities, between these two extreme rails of the group. Nor do I think we ought to expect such uniformity, and for the llowing reasons:

First. Whatever errors there may have been in determining the ss of metal of these rails or in the tonnages, as has been before escribed, will of course have an influence in determining the position f any rail in the group to which it belongs. And, as has already een said, while I do not think that these errors, whatever they may e, are sufficient to seriously obscure or counteract the general conlusions which the results are calculated to teach, yet these errors ay possibly be large enough to give some rail a position in the roup which it should not occupy.

Second. I am not aware that it is known as yet exactly what *ear* is, or what it is dependent upon. Some considerations in reard to the nature of wear will be advanced further on; but whether ear is a direct function of the tensile strength of steel, or of its longation, or of its elastic limit, or of its resilience, or any combinaion of these, or indeed, as seems somewhat probable, of the amount f distortion by bending that a piece of steel will suffer, is a problem et to be solved. It may be that wear bears a direct ratio to the longation within the elastic limit, or to the amount of work done ithin the elastic limit whenever a particle is worn off; or indeed, ear may be a direct function of the granular structure of steel, the ear being more rapid as the granular structure is coarser, or *vice ersa*. Or, finally, wear may be due to a combination of causes, nd each cause may require for its elucidation a different physical est. It is perhaps, therefore, not strange, in view of this want of nowledge, that in a series of steels arranged according to loss of etal, or on the principle of wear, the physical qualities which we re now able to measure should not show uniform gradations throughut the series. But, it seems to me, this reasoning does not end to throw doubt on our ability to draw conclusions that will e valuable from the work which we have in hand. For the uestion we are studying is not what does wear depend upon, but hat chemical composition, and what physical properties, are, in eneral, characteristic of such rails as have in actual service given ast loss of metal per million tons' burden? While the answer o this question may not solve the whole problem of wear, yet it annot fail to throw light on the relation between the chemistry and hysics of steel and its wearing capacity, which, after all, with our

present knowledge of steel metallurgy, is all the knowledge we
able to utilize.

Turning our attention now again to the tables before referred
I think that, notwithstanding we do not find absolute uniformity
has just been explained, yet no one can fail to observe, in genera
difference, both in physical properties and in chemical composit
between the slower-wearing and the more rapid-wearing rails. Th
in regard to the physical properties, I think it is entirely eviden
inspection, that, in the torsion tests, the slower-wearing rails in e
group, except perhaps on the high sides of curves, are characterize
general by lower height and greater length of diagram. In the ten
tests, again, the slower-wearing rails are, in general, characterized
lower tensile strength and greater elongation than the more ra
wearing ones. In the shearing tests, the same thing appears, viz
general, lower shearing stress and greater detrusion. And in
bending tests we see the same result, perhaps more strongly tha
any of the other tests, viz., that the slower-wearing rails are, in gene
those which have the lower bending stress and the greater amo
of deflection before rupture. In density, as would be expected,
slower-wearing rails have the greater density. Again, in the che
cal composition, the same thing is observable, viz., that the slow
wearing rails are characterized in general by the lower amounts of
substances determined, carbon, phosphorus, silicon, and mangan
while in phosphorus units, which, as you remember, I suggeste
an attempt to measure, in a degree at least, the combined influenc
these substances on the steel, the same thing may be seen, viz
general, the slower-wearing rails are characterized by the lo
numbers of phosphorus units.

Now, how shall we render evident to ourselves, in a more
gible manner, what seems, on inspection, to be the general te
ing of the results we are studying. I know of no method ex
that of combining these results together and forming avera
This, I believe, is the universal method applicable to all cases w
it is desired to draw conclusions from results embracing a num
of samples. If, therefore, we make a series of averages of the res
obtained, the individual peculiarities of the different rails will,
certain extent, disappear, and the general conclusions become m
evident.

Accompanying Plate 8 gives a number of such averages.
first line on this plate gives the averages obtained from com
ing together all the essential data of the eight slower-wearing r

f the first group. The second line gives the same data for the eight ıore rapid-wearing rails of the same group. The next ten lines ive the corresponding averages obtained from the remaining five roups. Turning our attention now to these averages, I think he same general conclusions which we have already obtained be- ome still more clearly evident, viz., that, perhaps with the excep- ion of the rails on the high sides of curves, the slower-wearing rails n each group are in general characterized by those peculiarities vhich we are accustomed to comprehend under the general term oft steel; that is, in general, diagrams of less height and greater ength, lower tensile strength and greater elongation, lower shearing tress and greater detrusion, lower bending stress and greater deflec- ion, and lower amounts of carbon, phosphorus, silicon, and man- anese, and lower phosphorus units. The exceptions to the law, if ve may so call it, will be readily noticed, and are, perhaps, insep- rable from averages formed from so small a number of samples as re some of these. The rails on the high sides of curves will be oticed further on.

With regard to the averages under consideration, it is perhaps ıteresting to notice that the slower-wearing rails are characterized hroughout the whole series by lower height of diagram and lower lastic limit in the torsion tests, by lower elastic limit in the an- ealed tensile tests, by lower bending stress and greater deflection ı the bending tests, by lower phosphorus and lower manganese in he chemical analyses, by lower phosphorus units and by greater ensity. It should be remarked that the high average silicon of the ower-wearing rails on grade tangents is caused almost entirely by ail No. 881, a rail whose chemical composition and physical proper- es are certainly anomalous. This rail has 0.48 of silicon together ith high carbon and manganese, and yet it gives with high ten- le strength, as would be expected, a very good elongation. I ay add that three determinations of the silicon in this rail were ade, in order to be sure that there was no error in the work. The eculiarities of this rail cause the average of which it forms a part differ from the other averages of the slower-wearing rails in sev- al particulars. If this rail is thrown out, and an average made om seven rails instead of eight, all the data fall more nearly into ne with the averages of the slower-wearing rails in the other roups. Thus, to give two or three examples, the average tensile rength of the unannealed tests becomes 75,143 lbs. instead of 0,625 lbs.; the elastic limit of same tests, 35,000 lbs. instead of

37,625 lbs.; the tensile strength of the annealed tests, 75,428 l
instead of 78,250 lbs.; the carbon, 0.301 instead of 0.324;
phosphorus, 0.082 instead of 0.076; the silicon, 0.048 instead
0.102; the manganese, 0.530 instead of 0.563; and the ph
phorus units, 31.3 instead of 34.8.

With regard to the rails on the high sides of curves, it will
observed that they do not seem to be governed throughout by
same law as the remaining groups. Whatever may be the rea
for this no one can fail to observe indications, which seem to po
in the direction, that on the high sides of curves the harder r
give the better wear. This is especially noticeable in the grou
rails on the high sides of level curves. It is, nevertheless, to
observed that in some of the data, especially height of diagram a
elastic limit in the torsion tests, elastic limit in both the annea
and unannealed tensile tests, in the shearing tests, in the deflection
the bending tests, and in the chemical composition, the groups
rails on the high sides of curves do not differ from the remain
groups. It would not be surprising if more extended data sho
show that a different quality of steel would give better wear on
high sides of curves than was found best in the other conditions
service. For on tangents, and on the low sides of curves, the k
of wear to which the rails are subjected seems to be different in
nature from the wear on the high sides of curves. On tangents, a
on the low sides of curves, the loss of metal is apparently due to
causes: 1st and principally, to rolling friction; and 2d, to the s
ing of the wheels. Now on the high sides of curves, in addition
the loss of metal due to these causes, there is also that due to
flanges of the wheels, or flange wear. Now flange wear may
only be different in its nature, but may also require different qu
ties in steel to most successfully resist it from what are found
where the rails are subjected principally to rolling friction. T
point will be referred to again when we come to speak of the
ture of wear.

Thus far we have confined our study to the consideration
averages obtained from the rails within each group. But if I
right, the value of averages increases with the number of samp
from which they are derived. It will be instructive, therefore
make averages of the slower and faster-wearing rails, embracing
large a number of samples as possible. But, as has just been notic
the kind of wear to which rails have been subjected, whether roll
and sliding friction or flange wear, may have an influence. It w

efore, perhaps be most instructive to make averages of all the which have been subjected to the same kind of wear, and see t their testimony is as to the physical properties and chemical position of the slower-wearing rails. Now forty-eight rails out he sixty-four we are studying did their service under similar mstances as to kind of wear; that is, forty-eight of the rails on tangents and on the low sides of curves, and consequently little or no flange wear, while sixteen of the rails were on the sides of curves, and were consequently subjected to both kinds ear.

accompanying Plate 8, line No. 13 gives the averages of twenty-four slower-wearing rails which did their service on ents and on the low sides of curves, and were consequently sub- d to the same kind of wear; while line No. 14 gives the aver- of the twenty-four faster-wearing rails that did their service r the same conditions. Line No. 15 gives the averages of the t slower-wearing rails that were on the high sides of curves, and No. 16 the averages of the eight faster-wearing rails under the conditions. What, now, do these four lines of results teach?

ith regard to the first two of these four lines, inspection seems e to show very clearly that the slower-wearing rails are charac- ed by those physical properties and that chemical composition h we are accustomed to comprehend under the term softer steel. ther words, we find that the slower-wearing rails are character- by lower height and greater length of diagram and lower elastic in the torsion tests; by lower tensile strength, lower elastic , and greater elongation in the tensile tests; by lower shearing s and greater detrusion in the shearing tests; by lower bending s and greater deflection in the bending tests; by lower carbon, phorus, and manganese, with a trifle higher silicon (caused by No. 881, as has been before explained) in the chemical compo- n; by lower phosphorus units, and by greater density.

ith regard to the next two lines, giving the averages of the rails ne high sides of curves, the testimony of the data is not uniform. length and area of diagram in the torsion tests, and the elonga- of the tensile tests, and also in a slight degree the carbon, indi- that the slower-wearing rails are the harder steel. In every item of the data, however, the slower-wearing rails are charac- ed by the same peculiarities that we have noticed in regard to ther rails, viz., lower height of diagram and lower elastic limit e torsion tests; lower tensile strength and lower elastic limit in

the tensile tests; lower shearing stress and greater detrusion i
shearing tests; lower bending stress and greater deflection i
bending tests; lower phosphorus, silicon, and manganese, with
phosphorus units in the chemical composition, and greater de
It may be that this want of uniformity in the data from the ra
the high sides of curves is due to the fact that our averages
embrace sixteen samples, and it may be, on the other hand, th
indefinite number of samples would give the same results. Or, a
it may be that this want of uniformity is due to a fact tha
already been stated, viz., that on the high sides of curves the l
metal is due to a mixed wear, partly from rolling and sliding fr
and partly from flange wear. If a certain quality of steel
successfully resists loss of metal due to rolling and sliding fri
and a certain other quality of steel best resists flange wear,
certainly it is not strange that in results obtained from a ser
rails, which have been subjected to both these kinds of wear at
there should not be absolute uniformity. If in the case of
rail the loss of metal was due almost entirely to rolling and s
friction, or, on the other hand, if the loss of metal was due a
entirely to flange wear, there is very little doubt but that th
would appear. But it is not difficult to conceive that there m
in any series of rails such a relation between the loss of meta
to both of these causes as to make it quite difficult to discover
kind of steel is best adapted to the high sides of curves.

Nevertheless, in an investigation of the extent of the one
consideration, perhaps the best that we can expect to do is to g
dications, and as far as may be definite conclusions, as to the k
rail best adapted to resist wear on the road taken as a whole
will, perhaps, therefore, not be wise to discuss further the pecu
ties of steel rails best adapted to any one kind of service, but to
What is the teaching of all the results we have obtained?
teaching will of course become evident if we make two average
one of the slower-wearing, and the other of the faster-wearing
the two embracing the whole 64 rails.

In accompanying Plate 8, lines Nos. 17 and 18 give such
ages. An inspection now of these two lines seems to me t
sent in a very striking light the differences in the results
physical tests and in the chemical composition, which are char
istic of the slower-wearing and the more rapid-wearing rails. In
particular of physical test and of chemical composition, exc
trifle higher silicon, which, as has been before explained, is c

by rail No. 881, the averages of the 32 slower-wearing rails are such as belong to what we are accustomed to call softer steel. In other words, the slower-wearing rails have on the average less height and greater length of diagram, with lower elastic limit in the torsion tests; lower tensile strength, lower elastic limit, and greater elongation in the tensile tests; lower shearing stress and greater detrusion in the shearing tests; lower bending stress and greater deflection in the bending tests; lower carbon, phosphorus, manganese, and phosphorus units in the chemical composition, and greater density. It seems to me, therefore, that so far as we may trust the teachings of 34 rails, all of which have actually done service, we can hardly escape the conclusion that the softer rails give the better wear.

In view of this conclusion, two questions very naturally arise:

1st. If the softer rails give the better wear why not make rails even softer than those in the series we are now considering; or, in other words, what is the limit of softness to which it is possible to go?

And, 2d. With our present knowledge of steel, is there any conception which will at all assist us in understanding why it is that the softer rails give the better wear?

As to the first question, I think almost every practical man will say at once: If your conclusions are correct that the softer rails give the better wear, why not make rails as soft as possible? indeed, why not use iron rails instead of steel? In answer to this latter question I think it may be fairly said, that such metal as is used for rails which we are accustomed to call iron is quite a different metal from that commonly called steel which is used for rails. From the processes used in their manufacture, iron rails are never free from slag, and lack homogeneity of structure, while steel rails, from their method of manufacture, are almost entirely free from slag, and are, or should be, practically homogeneous throughout. In the puddling process by which the iron for iron rails is made, the metal when taken from the puddling furnace is a dripping mass of iron and slag, and the amount of slag that is removed is dependent, in great part at least, on the subsequent working. Furthermore, in the subsequent operations before the rail is finished there are plenty of chances for non-welding, so that an iron rail might almost be cited as an example of non-homogeneity of structure. In the processes by which steel rails are made, on the other hand, the metal previous to the formation of the ingot is in a state of fusion, thus allowing the almost complete separation of the slag, and the formation of ingots, from

which rails are to be rolled, that are or should be practically h
geneous in structure. Now that rails made from ingot iron, if
a metal is possible, that is iron which before it became an ingo
in a state of fusion, would not, in actual service, wear slower
lose less metal per million tons' burden that passed over them
even the best rails in the series we are studying, is an assertion w
I think few men would be willing to make, and fewer still wou
able to maintain.

But, it seems to me, that there is a natural limit to the softn
steel for use in rails, which limit is determined by the servi
which the rails are to be subjected. It is evident, I am sure,
besides their ability to successfully resist wear, and to withstan
shocks and blows to which they may be subjected, rails have
another very important duty, viz., they must be able to hold u
load which is to pass over them without being deformed or squ
out of shape by this load. They must also have sufficient stif
so as not to be bent down between the ties by the load, and
give rise to a series of elevations and depressions in the track.
take an extreme case for an example, if we had a rail made of
no one doubts but that it would entirely fail to hold up the
between the ties, and would on the ties be deformed and squ
out of shape, probably, by the first train that passed over it.
those qualities of metal which enable it to hold up a load wi
bending, and to successfully resist deformation from compres
are generally comprehended with others under the term hard
In other words, to apply this to the case we have in point
harder the steel in the rails the less liable will they be to ben
tween the ties and to suffer deformation, or to squeeze out fro
loads which are above them. Here, then, is the limit of soft
The steel in the rails must not be so soft that they will bend be
the ties, or squeeze out of shape and become deformed fro
compression due to the superincumbent load.

Just exactly where this limit shall be placed is of course a
tion to be decided by the weight of the locomotives and cars w
are intended to run over the rail. On roads where the locomo
and cars are comparatively light, the rails could be made s
and consequently, if our conclusions are correct, the loss of meta
million tons' burden would be less than on roads using heavier
motives and freighting their cars with heavier loads. Just wher
limit of softness is in the case of the Pennsylvania Railroad, it
course impossible to say, but from an examination of all the

which have been tested at Altoona, amounting to nearly a hundred samples, I think that steel which gives a tensile strength of 65,000 lbs. per square inch or over will give very little or no trouble from bending or deformation in the track. It may be that this limit might be still lower, but with our present knowledge of the subject, and without further experimentation, I should hardly like to recommend it. Another consideration comes in here, and that is, it is a little more difficult to successfully make soft steel than to make hard steel, and it may be, therefore, that the difficulties of manufacture will help to establish the limit of softness.

As to the second question: Is there any conception which helps us to understand why it is that the softer rails give the better wear? I will say that in view of our absence of knowledge as to exactly what quality or combination of qualities of steel wear is a function of, the answer to this question becomes difficult. Nevertheless we may possibly get a little help upon this point by devoting a few moments to the consideration of what takes place when steel suffers loss of metal by wear. What then is the condition of the surfaces involved in wear? What are the forces which act, and what are the strains produced?

If I understand the matter correctly, no two surfaces ever have been made, or can be made, that are absolutely smooth. At the very best, the smoothest surfaces are made up of elevations and depressions, very minute, it is true,—perhaps almost infinitesimal and entirely incapable of measurement,—but nevertheless real elevations and depressions. When these elevations and depressions are tangible, we call the surface rough; when they are infinitesimal, we call it smooth. If, now, this reasoning is correct, the surface of the head of a rail, as well as that of the circumferences of the wheels above it, are made up of elevations and depressions, which, when the two surfaces are in contact, must more or less fit into one another. And it is this fitting in of the minute elevations and depressions of the two surfaces that gives rise to friction. If the two surfaces were absolutely smooth, there would be no friction, and, consequently, no tractive power in the locomotives, nor would the wheels under the cars turn around. Friction of this kind we are accustomed to call rolling friction. In reality, then, a rail and the wheel which rolls above it may be regarded as a rack and pinion with infinitesimal teeth, lacking, of course, the element of regularity as to the position of the teeth which characterizes a rack and pinion. So much for the surfaces involved in wear.

Now, what are the forces involved in wear, and what strains they give rise to? If I understand the matter rightly, there two kinds of friction which may occasion loss of metal by wear the case of rails: 1st. Rolling friction, which occurs when wheels turn around and the trains move forward; and, 2d. Slid friction, which occurs when the wheels turn around in the same pl as in the case of slipping drivers, or when the wheels do not t around and yet move along the track, as in the case of sliding whe It is probable, however, that by far the largest portion of the los metal which rails suffer is due to rolling friction; it will therefo perhaps, be sufficient for our purpose to consider this case only.

The forces which act between the top of the head of the and the wheels in rolling friction may, it seems to me, be regar as two in number. There is, first, a force acting directly downwa due to the weight of the locomotives and cars. This force may regarded as a vertical force acting perpendicularly to the head of rail, and is in action both when the train is standing still and w it is in motion. Secondly, there is a force acting parallel to head of the rail, due to the traction or impelling power of the l motives. In the case of the driving-wheels, this force may be s posed to act in the direction opposite to that of the motion of trains. In the case of all the other wheels, this force may be posed to act in the direction of the movement of the trains, and antagonism to this force by the rail that causes all these wheel turn around. In the case of the drivers, the amount of this f acting parallel to the head of the rail is sufficient to overcome total train resistance; in other words, to cause the train to move. the case of the other wheels of the train, acting individually, force parallel to the head of the rail is small, being only that ne sary to cause the wheels to turn around; in other words, to overc journal friction. The force parallel to the head of the rail acts when the train is in motion.

In the case of rolling friction, there is, of course, no except when both these forces are acting at once. But when forces are acting at the same time, their line of action mus regarded as in the direction of the resultant of the two forces. the case we are considering we have a vertical force and a horizo force acting at the same time, and the resultant line of action n of course, be a diagonal. In other words, in rolling friction, if conceptions given above are correct, the line of action of the f which produces wear must be regarded as a diagonal to the

ed by the head of the rail. In the case of the driving-wheels, liagonal is inclined toward the front end of the train, and in the of the other wheels it is inclined toward the rear of the train.

eturning for a moment to the conception previously men-ed, that the top of the head of the rail and the surface of the mference of the wheel are a rack and pinion, with infinitesimal , but without regularity in the teeth, let us see what kind of n would be produced in these minute teeth by a force acting onally to the line of the head of the rail. I hardly see how we avoid the conclusion that this strain would be a bending strain. he case when the infinitesimal teeth of the wheel and rail did not nto interstices, but struck against each other, in which case the s of the teeth only would be involved in the strain, then surely strain would be a bending one; and again, in the case in which teeth mutually engaged each other as a rack and pinion, so long here was motion of the train, which is a necessary condition of ng friction, it seems to me that the strain would still be that of ling.

f we are right in regard to the nature of the surfaces in-ed in wear and the strains produced, wear is simply the breaking ulling off of the infinitesimal teeth by the strains to which they subjected. And here we see why it is that the softer rails give better wear, for the harder the steel the more brittle it is; and more brittle the steel the more readily will these infinitesimal n be broken off by the strains applied. On the other hand, the er the steel the more readily will these infinitesimal teeth bend flatten down under the strain without breaking off. Or, to make statement general, if the nature of the steel is such that under the ns applied, whatever they may be, the teeth readily break off, ch is characteristic of hard steel, the more rapid will be the r; if, on the other hand, the nature of the steel is such that the n readily suffer distortion without rupture, bend and flatten down out breaking off, which is characteristic of soft steel, the slower be the wear. The above is not offered as a complete solution of problem of wear, but as possibly helping us to understand why that the softer rails give the better wear as we actually find do.

he data which have been obtained in the work done on this series ils, make it possible to get at some very interesting results as to rate of wear of rails under different conditions of service. Thus, example, what is the comparative rate of wear of rails on grade

tangents and on level tangents, or on grade curves and on level cu or on curves as compared with tangents, etc.? These compari may be made by taking the average loss of metal per million of all the rails which did their service under any one set of ditions, and comparing it with the average loss of metal of all rails which did their service under any other set of conditi This of course involves the supposition that the sixteen rails, for ample, which did their service on grade tangents were equall good, taken as a whole, as the sixteen which did their service on l tangents. Whether this supposition is absolutely true or not, I th the differences between groups of rails, that is the differences betw the groups that did their service under different conditions, hardly be great enough to lead us into serious error. The re of these comparisons is given in the following three tables. In t tables the first column denotes the kind of service to which rails have been subjected, the second column denotes the nu of rails from which the average loss of metal per million to column third is derived, and the fourth column denotes the rat the loss of metal for the kind of service between which the com ison is made.

TABLE NO. I.

EFFECT OF GRADE ON WEAR.

Kind of service.	No. of rails.	Average loss of metal.	Ratio.
Level tangent,	16	.0384	1 : 1.82
Grade tangent,	16	.0701	
Level curve,	16	.0706	1 : 1.80
Grade curve,	16	.1277	
Levels,	32	.0545	1 : 1 81
Grades,	32	.0989	

The above table shows the effect of grade on the wear of r The average grade for the rails on tangents was 64.75 feet to the m and, as will be observed, the rails on the grades lost 1.82 time much metal as the rails on levels. The average grade for the rai curves was 53.13 feet to the mile, and, as will be observed, the rail the grades lost 1.80 times as much metal as the rails on levels. average grade for the whole 32 rails which were on grades was 5 feet to the mile, and, as will be observed, the ratio of the loss of m on levels and grades is as 1 : 1.81. This table may be roughly sum up by saying that within the limits of our experiments, and wi

le of not quite 60 feet to the mile, the rails on the grade lose
ut 80 per cent. more metal per million tons than the rails on
ls.

TABLE NO. II.

EFFECT OF CURVES ON WEAR.

Kind of service.	No. of rails.	Average loss of metal.	Ratio.
Grade tangents,	16	.0701	1 : 1.82
Grade curves,	16	.1277	
Level tangents,	16	.0384	1 : 1.84
Level curves,	16	.0706	
Tangents,	32	.0542	1 : 1.83
Curves,	32	.0992	

he above table shows the effect of curves on the wear of rails.
average degree of curvature of the rails on grades was $4\frac{7}{8}°$, and,
vill be observed, the rails on the curves lost 82 per cent. more
al per million tons than the rails on tangents. The average
ree of curvatures on levels was $2\frac{3}{8}°$, and, as will be observed,
rails on curves lost 84 per cent. more metal than the rails on
gents. The average degree of curvature for the whole 32 rails on
ves was $3\frac{41}{64}°$, and, as will be observed, the rails on curves lost
per cent more metal than the rails on tangents. This table may
roughly summed up by saying that under the conditions of our
eriments, and on about 4° curves, the rails on the curves lose
ut 83 per cent. more metal per million tons, than the rails on
gents.

TABLE NO. III.

WEAR ON HIGH AND LOW SIDES OF CURVES.

Kind of service.	No of rails.	Average loss of metal.	Ratio.
Grade curve, low side,	8	.0801	1 : 2.19
Grade curve, high side,	8	.1754	
Level curve, low side,	8	.0500	1 : 1.82
Level curve, high side,	8	.0911	
Low sides,	16	.0650	1 : 2.05
High sides,	16	.1332	

he above table shows the relative rates of wear on the high and
sides of curves. The average degree of curvature of the rails
ne grades was $4\frac{7}{8}°$, and the average elevation of the rails on the
sides of the curves was $4\frac{7}{8}$ inches, and, as will be observed, the

rails on the high sides of the curves lost 2.19 times as much me
per million tons as the rails on the low sides of the same curv
Again, the average degree of curvature of the rails on the levels w
$2\frac{2}{3}\frac{3}{2}°$, and the average elevation of the outer rail was $2\frac{2}{3}\frac{3}{2}$ inches, a
as will be observed, the rails on the high sides of the curves lost
per cent. more metal than the rails on the low sides of the same curv
Finally, the average curvature of all the rails on curves was $3\frac{5}{6}$
and the average elevation of the outer rail was $3\frac{5}{6}\frac{1}{4}$ inches, and,
will be observed, the rails on the high sides of the curves lost 2
times as much metal as the rails on the low sides of the same curv
This table may be roughly summed up by saying, that under
conditions of our experiments, with an average curvature of ab
4°, and an average elevation of the outer rail of about 4 inches,
rails on the high sides of the curves wear a little over twice as
as the rails on the low sides of the same curves.

The data which have been obtained in the work done in this se
of rails furnish likewise the means of getting at some interest
facts as to the life of rails. It is of course a difficult thing to
just exactly when a rail is so worn that it can fairly be called w
out. And yet we can perhaps make a few assumptions which,
though not absolutely definite, may aid in throwing some light
this interesting question. If we take any standard 67 lb. rail,
suppose that the head is worn off on tangents or on the low side
curves until it is from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch lower than it was w
rolled, the amount of metal worn off will vary from about 6 lbs
10 lbs. per yard. On the other hand, if the rail has done ser
on the high sides of curves, the amount of metal worn off when
side of the head is worn up to the fish-plate will not be far fro
lbs. per yard. But as I understand it, the present practice on
road is, when a rail has become worn on the high side of a curve
to the fish-plate, to remove it to the other side of the curve, and
two or three years more wear out of it in that position. For
very general conclusions that we are after, therefore, it will perh
be sufficiently accurate to say, that a rail may fairly be said to
worn out when it has lost 8 lbs. of metal per yard. This assu
tion of course does not pretend to actually represent the loss of m
by wear which may or ought to be obtained from every rail be
it is worn out. In the case of the old standard section, it is probs
that rails may fairly be said to be worn out when they have
in the neighborhood of 8 lbs. per yard. In the case of the
standard section (section of 1875) a loss of from 10 to 14 lbs.

ard would leave the rail in as good condition as a loss of 8 lbs. per ard from the old standard section. In the following data, how-ver, a rail is assumed to be worn out when it has lost 8 lbs. per yard, nd from the figures given it will be easy to obtain the life of rails r any other assumed loss of metal. It will, of course, be borne in ind, that the figures which follow are strictly applicable only to ils of the same quality and doing service under the same con-tions as those from which these figures are derived. The conclu-ons must therefore be regarded as entirely general.

The following table shows what, with such average quality of eel as this report deals with, may be expected from rails in the arious conditions of service. The first column gives the number of e line in the table, the second column the kind of service, the ird column the number of rails from which the average loss of metal column four is obtained, the fifth column the number of million ns required in order that the rail may lose 8 lbs. of metal per yard, e sixth column the life, or number of years the rail would last in e north track, and the seventh column the life, or number of years south track. These last two columns are computed on the sup-osition that the yearly tonnage on the north track is 5,000,000 ns and on the south track 8,000,000 tons. On the north track, uring the 9½ years previous to July, 1879, the average annual ton-ge, including of course the locomotives and the weight of the cars well as their loads, has been 4,904,000 tons, while on the south ack, during the six years previous to July, 1879, the average an-ual tonnage has been 7,985,000 tons.

TABLE IV.

IE LIFE OF RAILS UNDER DIFFERENT CONDITIONS OF SERVICE.

o. of ne.	Kind of service.	No. of rails.	Average loss of metal.	No. of million tons to lose 8 lbs.	Life in years, North track.	Life in years, South track.
1	Level tangents	16	.0384	208.4	41.7	26.1
2	Grade tangents	16	.0701	114.1	22.8	14.2
3	Level curves	16	.0706	113.3	22.6	14.1
4	Grade curves	16	.1277	62.7	12.5	7.8
5	Low side level curves.	8	.0500	160.0	32.0	20.0
6	High side level curves.	8	.0911	87.8	17.5	11.0
7	Low side grade curves.	8	.0801	98 9	19.8	12.3
8	High side grade curves.	8	.1754	45.7	9.1	5.7
9	Tangents	32	.0542	147.6	29.5	18.5
10	Curves	32	.0992	80.6	16.1	10.1
11	Levels	32	.0545	146.8	29 4	18 3
12	Grades	32	.0989	80.9	16.2	10.2
13	Low side curves	16	.0650	123.1	24.6	15.4
14	High side curves	16	.1332	60.1	12.0	7.5
15	All conditions	64	.0767	104.3	20.8	13.0
16	32 slower wearing	32	.0506	158.1	31.6	19.8
17	32 faster wearing	32	.1028	77.8	15.6	9.7

In the above table the first eight lines show what may be exp
from rails of the quality we are considering in all the conditi
service, on the supposition that a rail is worn out when it ha
eight pounds of metal per yard, and that it carries five million
per year in the north track and eight million tons per year i
south track. It is, of course, very easy to obtain from the fi
given the life of rails under any other supposition. Thus i
tonnage doubles, the life of the rails would of course be one-h
great as that given above. On the other hand, if a rail is n
garded as worn out until it has lost twelve pounds of metal per
the life of the rail, the tonnage being the same, will be on
greater than the figures given above. The remaining lines o
table, except the last two, show the life of rails under different
binations of the various conditions of service. They are give
the sake of information, and perhaps do not need any special
ment or explanation. The first eight lines, of course, give the
that are most valuable. With regard to these data it will be n
that on the high sides of grade curves, the average degree of curv
being $4\frac{7}{8}°$ and the average grade 64.75 feet to the mile, a rail of
average quality as those we are studying, and on the supposi
above given as to loss of metal and tonnage, may be expected t
a little less than six years in south track and a little over nine
in north track. On the low sides of the same curves the lif
little more than twice as long. This table may, perhaps, be
summed up by saying that rails have their shortest life on the
sides of grade curves, next on the high sides of level curves, ne
the low sides of grade curves, next on grade tangents, next on
sides of level curves, and their longest life, as would be expecte
level tangents.

It is an interesting question whether it will be possible to ge
high number of years' service given under some of the condi
above in actual practice? At first sight this seems improb
But so far as loss of metal by wear is concerned, I see no e
from the conclusions given above, the conditions remaining the s
Other causes may, of course, take a rail out of service. And
doubtedly these other causes, such as crushing, breaking, disto
of head, and especially uneven wear, will all combine to mak
average life considerably less than the above figures show. N
theless, the life of rails due to wear alone being known, it wi
course, be the aim to diminish the removal of rails from the

to other causes as much as possible, and thus approximate ely to the best results.

ne word more in regard to the life of rails. The last two lines he above table give the same items of information, computed in same way, as are contained in the remainder of the table. But ie first of these two lines the data are such as would be obtained ll the rails in the series had been as good as the average of the ty-two slower-wearing or better rails, while the second of these lines shows what would result if all the rails had been the same ie average of the thirty-two faster-wearing. As will be observed, ll the rails in the series had lost metal or worn as fast as the rage of the thirty-two faster-wearing rails, the best that we could ect under the suppositions given, as to loss of metal and yearly nage, would be a tonnage of about seventy-eight millions and a of a little less than ten years in south track. On the other hand, ll the rails had been as good as the average of the thirty-two er-wearing or better rails, the tonnage and life would be just it double these figures. In other words, the slower-wearing rails on the average about twice as good in quality as the faster-wear- and would consequently give about twice as high a tonnage and e as long a life.

hese data may be put in another form, which perhaps will be fairer way of looking at them. The average life of the sixty- rails we are studying, on the supposition that they are worn out n they have lost eight pounds per yard, and that the yearly ton- e in south track is eight million tons, is, as is seen in third line bottom of above table, thirteen years. If, now, we were able btain steel rails as good in average quality as the thirty-two er-wearing rails in our series, this average life would be almost nty years, or an increase in life of over 50 per cent.

he question now arises, How shall the results of this work be zed? I think it is entirely evident that the direction in which t must tend in order that these results may be utilized is toward ring softer steel. And just here, perhaps, is the proper place to ce what seems to me a very important point. As you know so this is our second investigation upon steel rails. The first in- igation, as has already been stated, dealt principally with the tion as to the relation between the chemical and physical prop- s of steel rails, and their power to resist crushing and fracture rack. The conclusion reached, as you remember, was that the r rails are less liable to crush or break in service than the harder

ones. Now in this second investigation we find that the softer ra
give the better wear. In other words, the softer steel makes ra
which are not only less likely to crush or break in service, that
rails that insure greater safety in the track, but also the sof
steel makes rails that give better wear. And, unless the conclusio
upon these two points can be overthrown by an equal amount of wo
as carefully and conscientiously done, I do not see how the Pe
sylvania Railroad can, in the future, do otherwise than use every eff
to secure softer steel in its rails. And for this purpose I can
nothing better than that for the future the rails shall be bought
specifications, and subject to inspection and test before they are
cepted. What specifications, therefore, does it seem wise to propo

1st. As to chemical composition. It seems to me that it would
entirely philosophic to take as the specifications for the chemical co
position the average analysis of the 32 slower-wearing rails in
series we are studying; especially as this analysis confirms the w
done on the 25 samples of steel rails in the first report to you
this subject. This average analysis is as follows:

Carbon, ...	0 334 per cent.
Phosphorus, ...	0 077 "
Silicon, ...	0.060 "
Manganese, ...	0.491 "

But, as was stated in that report, the amount of phosphorus ab
given is rather lower than the manufacturers of steel rails in t
country can comfortably work. It would perhaps, therefore, be w
to increase the amount of phosphorus a little and diminish so
of the other hardeners proportionally. In view of this reasoni
therefore, I see nothing better than to re-recommend the specifi
tions as to chemical composition in our first report, as follows:

Phosphorus, not above, ...	0 10 per cent.
Silicon, not above, ...	0.04 "
Carbon, between 0 25 per cent. and 0 35 per cent., with an aim at, ...	0.30 "
Manganese, between 0 30 per cent. and 0.40 per cent., with an aim at, ...	0.35 "
Sulphur and copper, ...	No specifications

2d. As to physical tests and inspection. What physical tests a
inspection shall the Pennsylvania Railroad prescribe for its rai
The inspection which is now practiced seems sufficient to excl
rails whose defects are evident to the eye. As to the quality of

something further seems to be needed. Now, a physical test to rmine the quality of the steel must, in the first place, be of such a re that it will protect the consumer; that is, enable him to re- such steel as is not fitted for the purpose for which it is designed e the metal. In the second place it must be practicable; that must not require too elaborate appliances nor too much labor ake the test; and finally, it must not be so severe on the manu- rers as to cause unnecesssary hardship and loss in manufacturing metal. What physical test now will fill these requirements? data which have been obtained in the work done on the rails we been studying enable us to prepare specifications which will e it possible to use any one of these four kinds of tests, viz., on test, tensile test, shearing test, or bending test. Thus we d, and if so desired will, prepare specifications leaving it optional the steel-rail manufacturers which test shall be used. And I be permitted to say here, that if the torsion test is chosen the of the slower-wearing rails so strongly confirm the position n in the first report to you on this subject, that I do not see how hing else could be done than to re-recommend the specifications e torsion test in that report.

ut in looking over the physical tests of this series, I think it is ly evident that the shearing tests and the bending tests bear a r relation to the loss of metal per million tons than any of the r tests. It is true that there are some anomalous cases even in e tests; some cases that do not exactly fall into line. In the of the bending tests this may in part, perhaps, be accounted for he fact that these tests were made on samples cut from the web he rail instead of from the head, where the wear took place. Cloud has found by a series of companion tests, made from les cut from the head and web of the same rails, that the physi- ualities of the metal in the head differ somewhat from that in veb, and, as has just been said, this may to a certain extent ex- some of the anomalous cases in the series of bending tests. closer agreement, however, between wear and the physical ties of metals which are measured by shearing and bending, ests that, perhaps, a shearing or bending test would be the best o apply. And here I would like to express my judgment that test suggested by Mr. J. T. Smith, General Manager of the ow Hematite Steel Works, several years ago, is, all things con- ed, the best physical test ever proposed for the examination of rails. Mr. Smith proposed that the fish-plate holes should be

punched by a registering press, and that the quality of the s
should be judged by the pressure required to punch these h
With the proper specifications as to the upper and lower limit of
punching strain, both steel that was too hard and steel that
worthless, from being spoiled in manufacture, could be reje
And, still further, this punching test would be a shearing st
and, at the same time, would enable a judgment to be formed of
quality of the steel in every rail. A slight reaming of the h
after they were punched would remove the ring of metal injurio
affected by the punch, and leave the rails uninjured as to stre
at the fish-plate holes. Unfortunately, however, with present ap
ances the punching test seems to be impracticable.

It would perhaps, therefore, be best to apply a bending
especially if our analysis of the strain applied to the infinitesi
teeth of the rail in rolling friction is a correct one. It wil
remembered that the theoretical considerations of what takes p
in wear seems to plainly indicate that the strain applied to
minute elevations on the rail is a bending strain. If this is t
there could be no better test of the quality of steel to resist w
than a bending test.

Now there are four ways in which a bending test could be appl

1st. The drop test. This test is in good use in England at
present time to determine the quality of steel for rails. But
disposition in this country, so far as my knowledge goes, seem
be to regard it as a somewhat crude test, and it is, therefore, be
laid aside in favor of more accurate modes of testing.

2d. A piece of steel hammered out from a crop-end could be
under a steam-hammer. This test was in use on the Pennsylva
Railroad for some time to determine the quality of the steel, but
crudity, and the fact that the metal was manipulated after it
been rolled, and thus did not represent the steel in the rails, seem
me very justly to have led to its abandonment.

3d. A crop-end or piece of the rail just as it was rolled may
bent in a testing-machine. With proper specifications this
would undoubtedly give entirely satisfactory results. With a pro
upper limit as to the maximum load required to bend the rail, s
that was too hard could be rejected, and, with proper specificati
as to the amount of deflection the steel should stand before ruptu
steel that was worthless from being spoiled in manufacture co
likewise be rejected, and thus only good material be received. W
would be glad to prepare specifications for this test if desired.

A test-piece cut from the rail could be bent in the testing-
ne. This test would undoubtedly likewise give us entirely
ctory results. And for this test we have the data already at
from which to prepare specifications. One or two things,
er, should be borne in mind: 1st. The tendency of the steel-
anufacturers in this country at the present time is to make
uch harder than is desirable, if our conclusions as to the wear-
ality of steel are correct. This tendency must of course be
ized in preparing the specifications. And, in my judgment,
ndency will best be met by assigning an upper limit to the
um load in the bending test. 2d. While our desire is to
softer steel for rails, it must be remembered that steel may be
nipulated in manufacture as to render it very inferior in
. Our specifications must therefore enable us to reject such
ess steel. This, I think can be successfully accomplished by
ng the test-pieces to bend to a certain angle before rupture.
ould therefore recommend that for all steel rails received
e Pennsylvania Railroad Company in future the following
g test be prescribed: The test-pieces shall be cut from the
the rail and shall be 12 inches long, 1½ inch wide, and ½
ick. These pieces shall be tested in the manner prescribed
preceding part of this report, and on all steel accepted these
ces shall stand a maximum load of not over 3000 pounds,
all bend not less than 130° without rupture.

ives me pleasure to make acknowledgments for services ren-
o those who have assisted in this investigation. Mr. J. W.
engineer of tests, has had charge of the physical tests and
rements, and has either made them himself or had them made
his supervision. He has also from time to time made sug-
s and contributed to the development of the ideas that have
orked out during the investigation in so many instances that
ld be difficult to enumerate them. Mr. A. O. Dayton, assist-
gineer of tests, made all the measurements with the planime-
d likewise assisted in making the physical tests. Mr. H. L.
at present chemist of the Colorado Iron and Coal Company,
, Colorado, did a considerable portion of the chemical work.
osphorus and manganese were principally determined by him.
icon was determined by Mr. Wells and myself working to-
The carbon was determined by myself. The services of
istant, Mr. Theo. J. Lewis, have been almost invaluable in

every part of the investigation. His patience, industry, and car attention to details can only be appreciated by those who know l laborious has been the work of collecting and working out into present form the information herewith presented.

Very truly yours,

CHARLES B. DUDLEY,
Chemi

ON RAIL PATTERNS.

BY A. L. HOLLEY, C.E., LL.D., NEW YORK CITY.

THERE are regularly manufactured in the eleven Bessemer s rail mills of the United States, 119 patterns* of steel rails, of different weights per yard. This list does not include patterns wh although still largely in use, are regarded by experts as obsolete, which would swell the number to nearly 300; nor does it incl all the patterns for which rolls are kept on hand to fill a poss demand; nor does it include extra patterns rolled in one finish groove by opening or closing the rolls so as to get different weig with the same contours. The list embraces only those separate p terns which are subject to *current orders*.

How thoroughly modern these patterns are, is shown by the that of the whole 119, there are but five patterns of conspicuously shape; all the rest more or less completely illustrate the stand features,—a heavy head, light web and flanges, and a good angl hold the fish-plate. Sixty-two per cent. of the patterns have "Chanute" head, which was not designed until 1874.† Sixty-four cent. of the 119 patterns are embraced under five weights per ya three only of these vary from standard type; there are thus patterns, all of them modern and standard, to represent five differ weights, for which five patterns would perfectly answer. Of the lb. rails, there is only one of the pear-head type, while a dozen the bevelled head templets cannot be distinguished from each ot

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* From all the works 188 patterns were sent to me as standard. Of the found 119 different shapes and 69 duplicates.

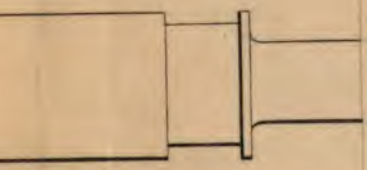
† Since this paper was read I have seen at the Bethlehem Iron Works the te let of a 68-pound Lehigh Valley rail, with the bevelled head, usually called "Chanute" head, and marked "Templet of 1872." This is shown on Plate II learn that iron rails, with bevelled heads, were rolled at Bethlehem prior to 18

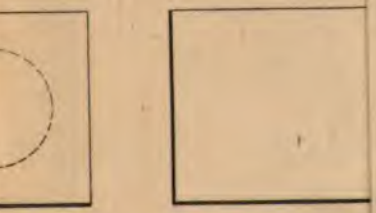
Dudley.—Plate 1.

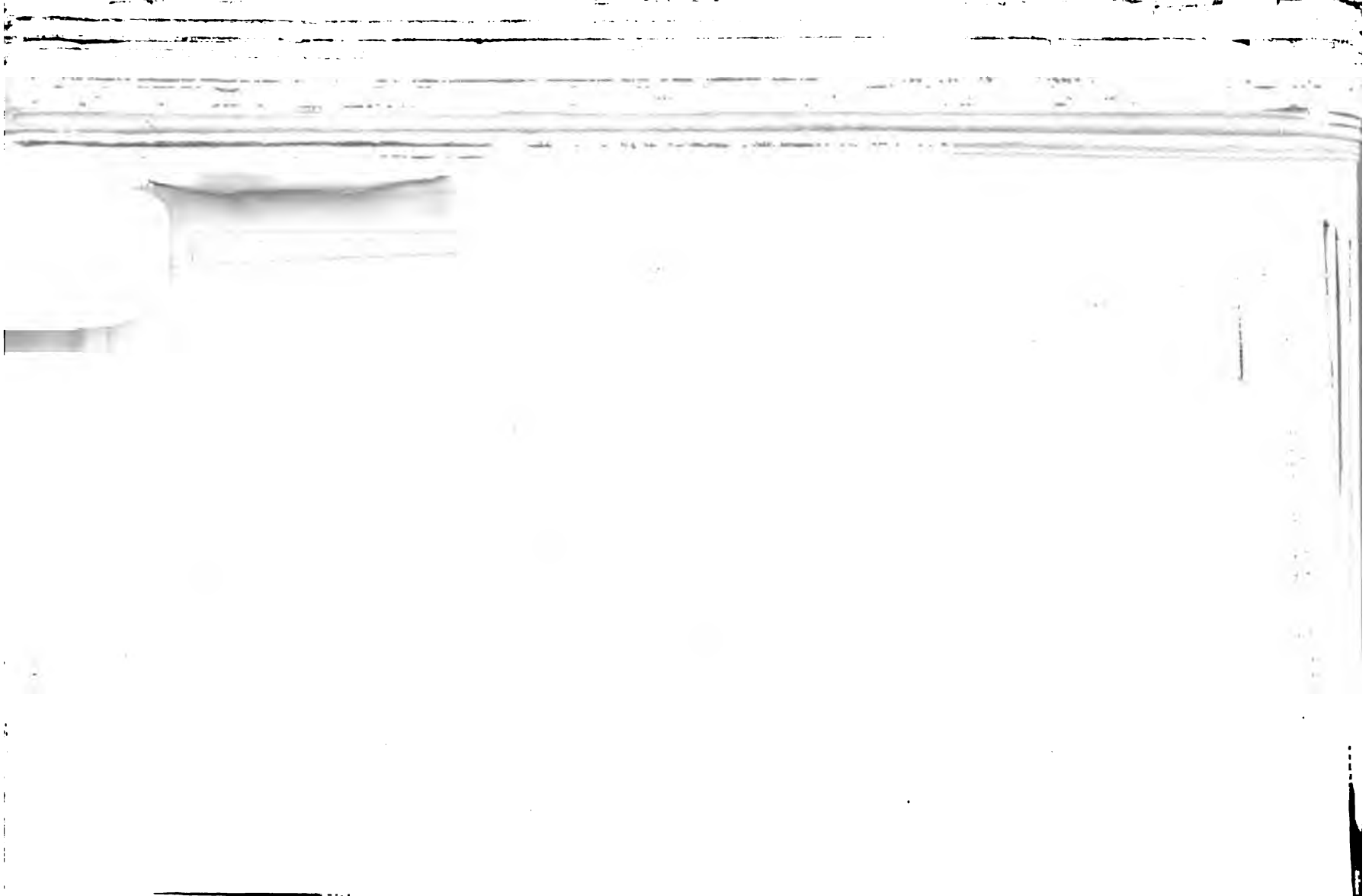
1

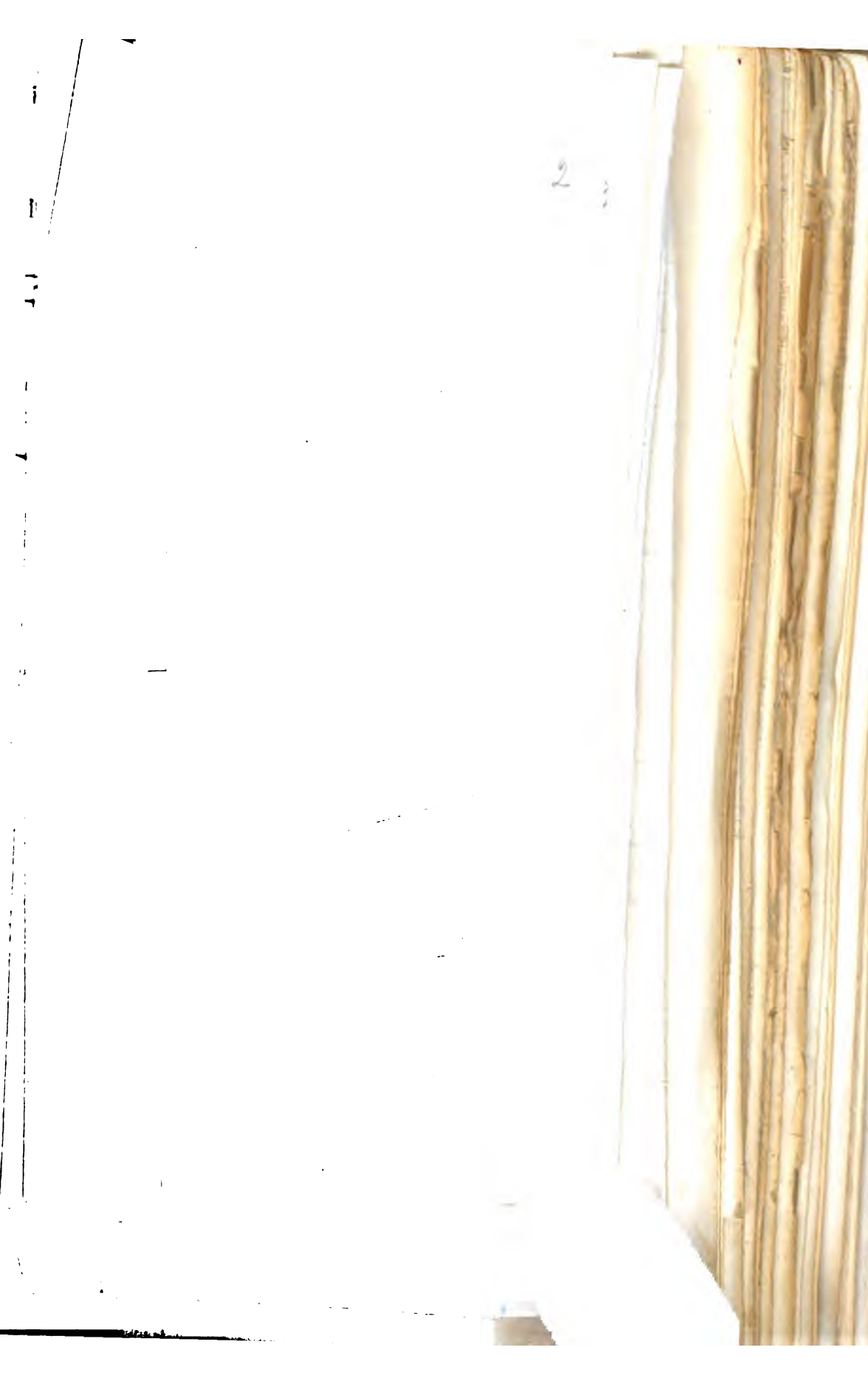
E

Scale - Full Size









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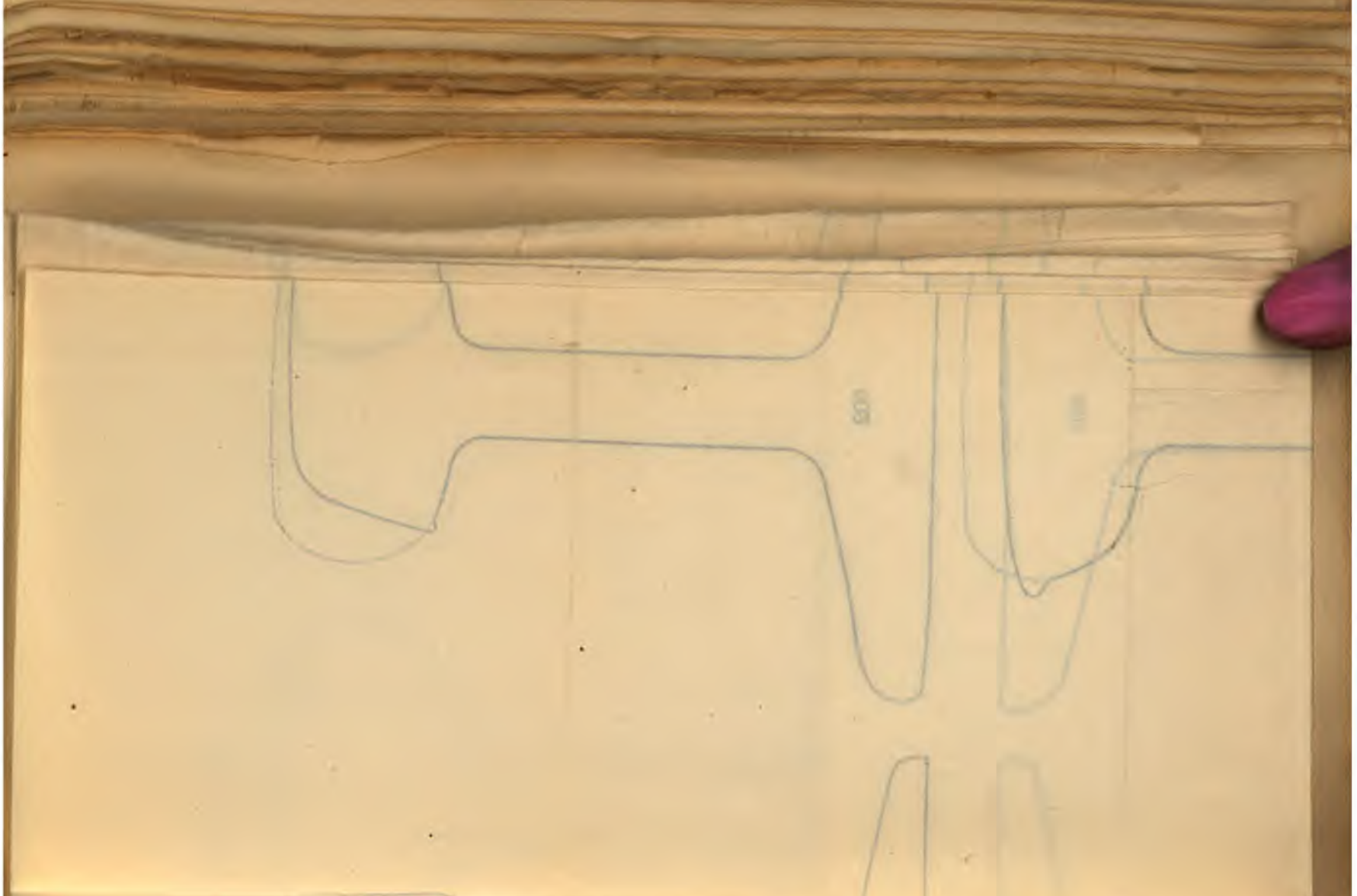
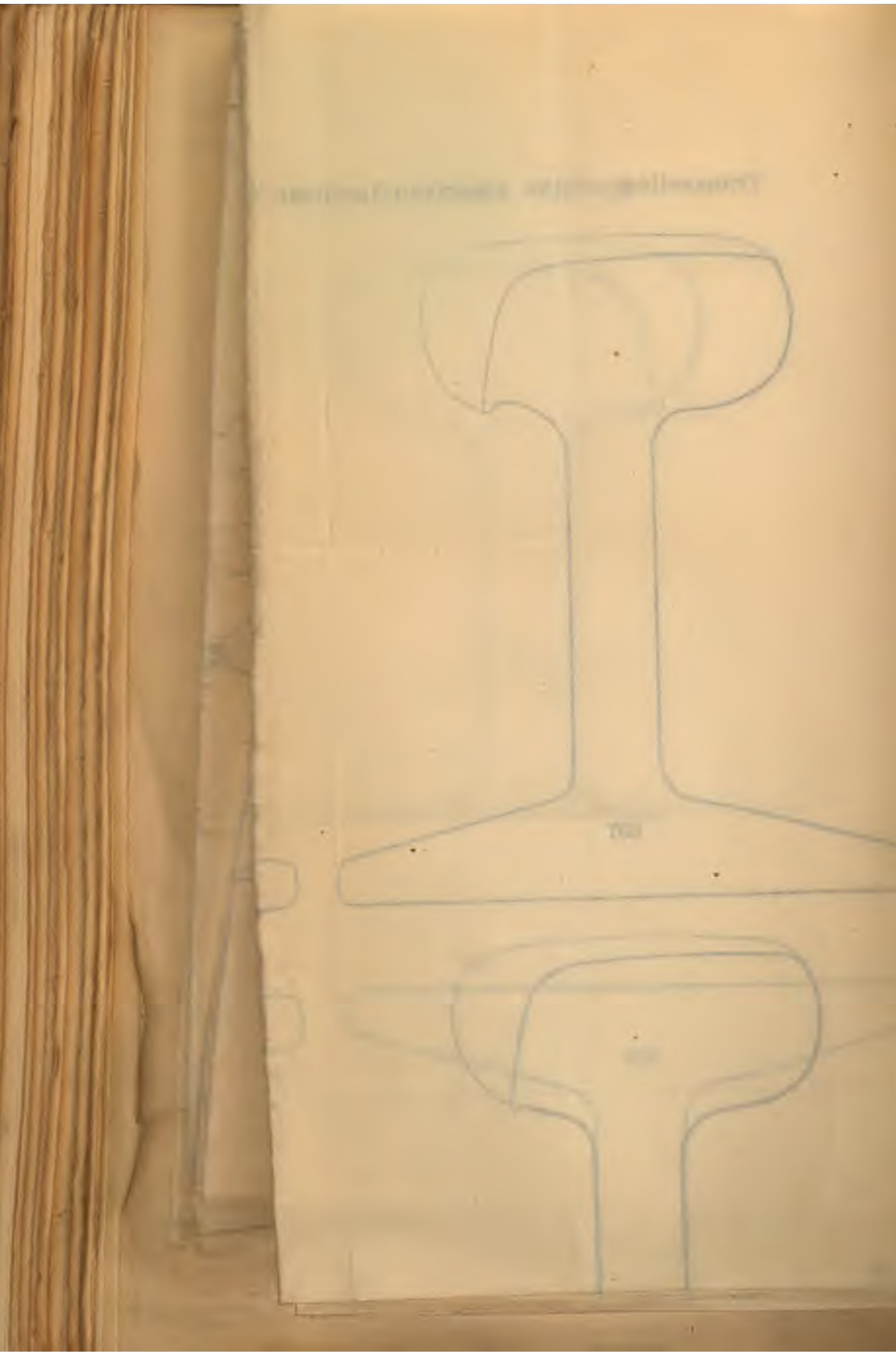
3



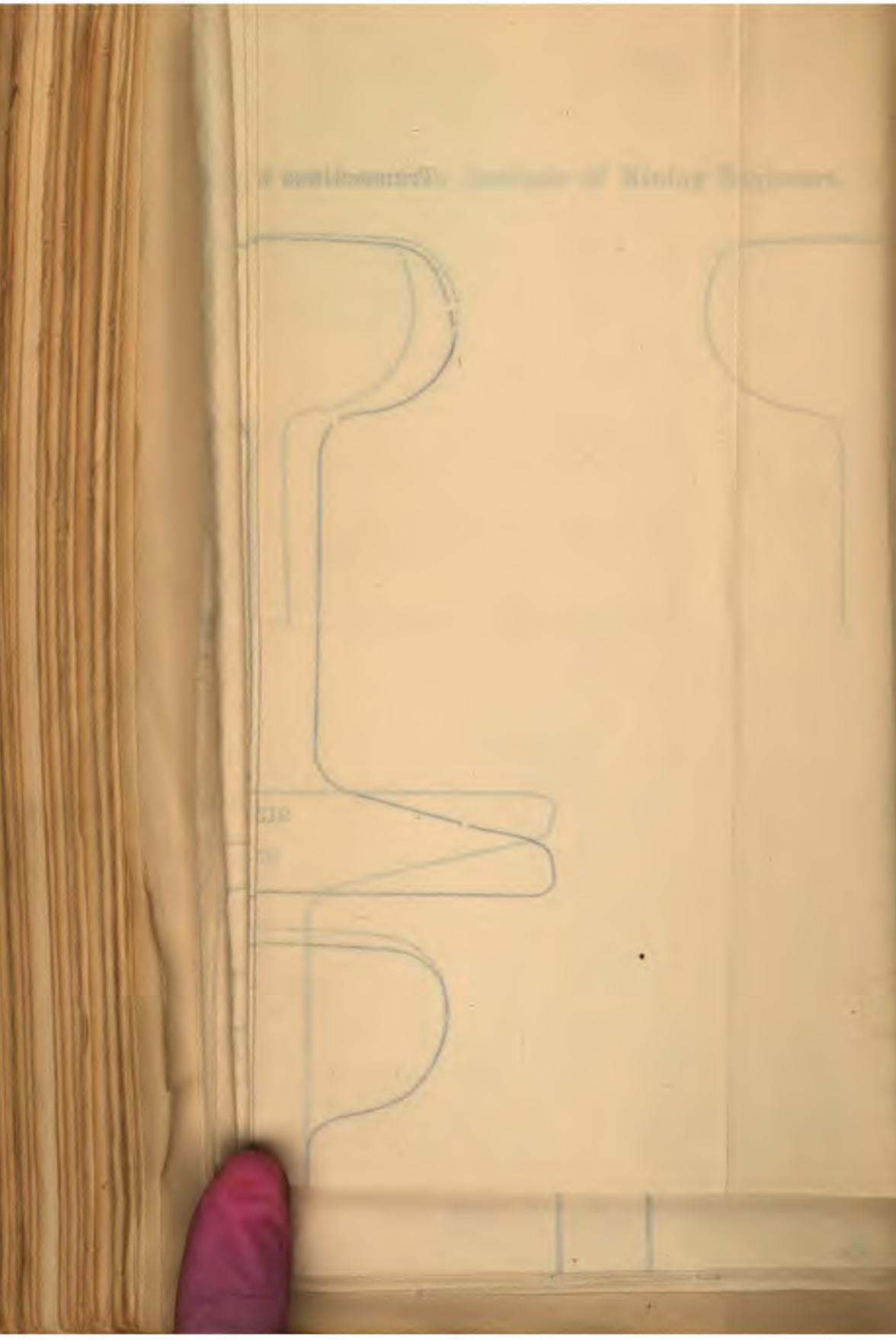
A

Plate 2.

Dudley.—Plate 3.



Dudley.—Plate 4.



5

ON.	ANALYSES.		
n of m.	Manganese.	Phosphorus units.	Density.
3	.435	24.2	.28143
3	.656	32.7	.28214
9	.610	35.7	.28214
0	.472	33.9	.28143

ILE TESTS.

ga-	ANNEALED.	
	Tensile strength.	Elastic limit.
	89,000	45,000
	62,000	30,000
	69,000	35,000
	62,000	25,000
	71,000	36,000
	76,000	35,000

CS.

NEALED.	
Elastic limit.	
7,625	
6,625	
2,250	
8,250	
6,500	
7,000	
6,625	
8,000	
4,250	
0,250	
6,750	
0,250	
5,833	
7,958	
6,625	
8,625	
6,031	
8,125	

except by laying them together; and yet no less than 30 patterns are in current use for the 60-lb. weight, which is obviously 29 patterns too many. Table I gives particulars of the 119 standard patterns.

The object of this paper is 1st, to show that while this multiplication of rail patterns is an annoyance and an expense to rail-makers, it is a source of immense loss to railway companies; 2d, to review the suggestions of experiment and practice regarding the shape of steel rails, and to suggest a method for the adoption of the few standard patterns which are necessary.

First.—The cost of a set of three-high finishing rolls for steel rails, with guides and guards fitted, averages about $1500. The number of sets of rolls in use at the eleven mills to produce the 119 patterns —several mills making the same patterns—is 188, and their cost was about $282,000 or nearly nineteen times as much as it would have been for the maximum requirement of ten patterns. But this does not give an adequate idea of the expense of multiplying patterns. New sections are constantly brought out by railway companies, and as most of the 119 are recent, it is safe to suppose that this process of multiplication will naturally go on. Again, each of the mills rolls many of the same patterns, sometimes for the same roads. It is not probable that all the mills will be called on to roll all the patterns, but it is not improbable, if this system continues, that each mill will be called on to roll a large number of them. One of the mills already rolls 29, another 25, and three of them roll 21 each of the 119 modern patterns. If the mills average even 30 patterns each, the 330 sets of rolls required will have cost half a million of money.

The cost of changing rolls is a much more serious expense than the cost of rolls. The time of changing rolls varies in different mills, but it probably averages about 2½ hours, or the time required to roll say 35 tons of rails. The number of changes made also varies very much. Rolls that do a fair week's work, say 2000 tons, without dressing, may be replaced by rolls of another pattern, on Sunday, without loss of time; but the great majority of orders are not for 2000 tons; they are more often for 500 tons and sometimes for 100 tons. One mill had to change rolls as many as four times a week, for some months, and I presume this is not an unusual experience. Were each of the eleven mills obliged to change rolls and patterns only once during the week, not including Sunday changes, they would together lose, at the reasonable profit of $5 per ton on rails, and allowing the usual stoppages for repairs, above $90,000 per year.

The looking after and keeping up of so many patterns of rolls, and the innumerable varieties of drilling and slotting, involve extra men and expense; but they are chiefly deprecated by rail-makers as an annoyance rather than as a direct expense. With all the care that must be taken in large organizations, mistakes and misunderstandings about them will constantly arise between makers and users, when each customer wants a different rail, different variations in standard length, different percentages of short rails, different sized fish-holes, different pitch of fish-holes, different patterns of fish-plates, different length of fish-plates, different slotting, different bolts, different tests, different everything.

Second.—The cost to railway companies of multiplying patterns is far more serious, chiefly in one direction,—it prevents rail-makers from keeping standard rails in stock. If rail-makers could roll and stock standard patterns, when special orders were slack, they could prevent the excessive rise in prices, which the scarcity of rails from time to time creates. It cannot be denied, after the unvarying experiences, that many railway managers do not buy largely when rails are cheap; they put off and put off ordering their full supplies hoping for lower rates, until the necessities of the track can be postponed no longer. Just at this time a hundred other roads are in the same condition—they are all pinched together—and off they all rush to the rail-mills to get first served, and up go the prices of rails $40 or $50 per ton.

The difference between the average minimum and the average maximum prices of rails on the books of one steel company was $43.5 per ton in nine months. It is probable that 200,000 tons of rails could have been added to the product of the eleven Bessemer steel mills during the year prior to the rapid rise in prices. When the railway companies did buy the 200,000 tons, they paid an advance of $30 to $40 per ton. If these rails had been in stock when the demand came, the simultaneous wants of a large number of roads could have been met without much increasing the price. Supposing the price to have been only $10 less than the average high rates, the saving to railway companies would have amounted to the respectable sum of $2,000,000. And the rail-makers would have been better off too, because they would have got fair prices for their whole product. High prices at one end of the year did not compensate for the excessively low prices at the other end, because when rails were dear pig iron and labor were equally dear.

The argument is not that stocking standard rails will always ma

them cheap. Their value, like that of all products, changes with the general condition of trade. Rail-makers would rather produce, even without profit, for a few months in the year, than to lose their good men and break up their smooth-working organizations. Stocking standard rails would enable them both to produce cheaply and to sell at a fair price; it would therefore check excessive fall as well as excessive rise in prices.

The argument is 1st, that running mills on half or three-quarter time or letting them stand for one year, and the next year suddenly filling them with orders for short delivery far in excess of their capacity, is simply a *waste* that railway companies have to pay for in the long run. No fact regarding the iron manufacture is better established than this,—that regularity in working and gradual increase of capacity, rather than sudden fluctuations, are to the advantage of all concerned. Running a 100,000-ton mill at a 70,000-ton rate does not create nor save any money, however much it may temporarily bring down prices. On the contrary, it wastes the time of the men, it wastes fuel, it wastes machinery, it wastes capital; and for all this waste, neither the railway, nor the steel-maker, nor the workman, nor anybody has saved anything, or got anything more to show than they would have got out of a fire or an earthquake.

2d. Excessive production is also wasteful; it strains both men and plant, and it does not allow time for repairs just when they are needed. The wear and tear of loose joints and connections in machinery increases, not uniformly, but at least as the square of the time they are allowed to run without repairs.

The same rule holds in the preliminary industries of making pig and mining ore. Excessive output is wasteful, and a large decrease of output, either by working short turns or by standing, is particularly wasteful of the time of men and the use of plant. All the men and all the plant must be used, and in so far as they are not fully used, their capacity is simply wasted.

For all this railway companies have to pay in the long run. Any temporary cheapness of rails must be compensated. They cannot be and will not be produced, for long periods, without a fair profit, nor is it to the interest of a railway or of the community, that any industry should be prosecuted without a fair profit.

3d. Besides the waste due to this fluctuation of output, railway companies have to pay for maintaining a system by which they cannot get rails when they want them. Of course rail-makers will

work first for those who pay most, and a high rate for immediate ac
commodation fixes the general price for months to come.

Rail-makers would gladly stock standard rails just as wheel-maker
stock standard wheels, if they could be sure that the rails were stand
ard and could be sold just as readily as those made to special order
As we have observed, this would save them trouble and anxiety, a
well as loss, and it would enable them to keep their organization
and plants in economical working order, so as to produce at th
minimum cost.

There is still another consideration: On account of the sudde
scramble for rails, due largely to there being no stock to draw from
150,000 tons or more per year have had to be imported at the the
ruling high prices. American rail-makers would have gladly mad
these rails during slack times. As it is, American mill-owners an
American workmen have now lost them altogether, and the railwa
companies have paid extravagant prices.

Third.—The question now arises, How is the difficulty to be remo
died? The answer involves a review of its causes.

1st. The early steel rails were naturally made to the existing iro
patterns. These were generally pear-headed, in order to prevent
the sides of the head from breaking down, and were therefore no
adapted to fishing. When the quite different physical charact
and behavior of steel became known—first of the hard steels an
then of the modern rail steels—many and necessarily diverse attemp
were made to adapt the shape of the rail to the new and varying ma
terial. Some of these attempts were scientific, and their general r
sults were similar, but the exact patterns largely differed. On th
contrary, some railway companies, utterly disregarding the accumu
lating knowledge of steel, stuck to the old pear-head; and as groov
for rolling iron have too much draft for steel, new rolls had to b
made for old patterns, thus still farther aggravating the difficulty. F
nally, in 1874,* Mr. Chanute, of the Erie road, started a really scie
tific investigation to determine the shape and proportions for ste
rails. This we will consider farther on.

2d. There is another cause of the multiplication of patterns, mo
potent and more difficult to remedy than any intrinsic cause. It
the egotism of certain engineers and officers of railways. I do n

* Since reading this paper my attention has been called to an improved form
steel rail, differing only in the head, from the more modern patterns, and design
by Mr. Ashbel Welch, in 1866.

refer to those honestly differing opinions which are founded on observation, even if that observation is incomplete and one-sided. I refer to the determination of certain persons who dictate patterns to railways—and these persons are not a few—to use no pattern that any other manager has invented, but to vary from all standard patterns, for no reason whatever, except to inflict their own individuality upon some feature of the interest confided to their care. I cannot, of course, give names and particulars in a public paper; but there are plenty of names and instances known to rail-makers and to dealers, and to the railway fraternity. There are instances of men signalizing their accession to power by the imposition of a rail pattern which is not only new, but inferior in every way to patterns in current use. Some of these tinkers think they win the admiration of boards of directors by thus showing up the general ignorance and their own technical genius. They fondly believe that having "Stiggins's" rail pattern talked over in the mills and railroad offices gives them a certain immortality. It does.

3d. There is another cause of multiform rails which is just as absurd as the last named. I give a typical instance—a case in which, I am sorry to say, I personally figured, for I had to design the rail for a steel-making client. A railway manager wanted a better head on his otherwise fair rail, but he insisted that it must fit his standard fish-plate. No standard rail would fit his fish-plate, although several suited him in other respects. Nothing would do but a bran new pattern, and it is now one of the 119. This railway company is to be congratulated. It will have saved, during a period of a dozen years, perhaps $100 worth of special joint fastenings at each end of long sections of replaced track, and where an occasional bad rail is replaced before the general renewal.

The following practical questions are first in order: What are the proper proportions for steel rails? How were they determined? Who is the authority? The art is now so far advanced that we can answer these questions. The proportions and even the contours are those adopted in 62 per cent. of the 119 standard patterns; they were determined by experiment and practice, and the authority is the majority of railway managers and all the scientific experts. These proportions and contours are illustrated by the 10 patterns on Plate I.

It must be constantly borne in mind that the experience in iron rails is no criterion for steel, because modern rail steel, including the soft steel made on Dr. Dudley's formula, is a comparatively uniform

product, varying less than other large classes, such as tool
even boiler-plate steel. Rail irons, on the contrary, especia
just preceding the steel era, could not be classed under on
if indeed they were of the same genus. They included eve
ble mixture of metalloids, slag, and iron, from the rotten
erate that crushed under a light traffic when piled into
pound rail (Plate II),* to the old Reading 45-pound rail (
made of reworked merchant bar and nearly as homogen
durable as steel. It is not surprising that iron rail patte
various, when nearly every lot purchased had its particula
of going to pieces. One railroad superintendent could gue
as another at a pattern that would not stand; scientific inq
not got around to the rail business.

Let us examine the steel rail pattern in detail.

1st. A few years' use of steel abundantly proved that th
the head do not break down, even if quite thin. The onl
mechanical destruction is the wearing out. The occasional
of the ends, and the very rare splitting and crushing of the
where, are due to the bad casting of ingots, and to workin
ingot tops into rails. The breaking of rails which are prop
is due to chemical defects. The strength of steel thus re
practicable to cut out the underside of the head, leaving
flat table to hold a fish-plate, and so to sustain and preserve
of the rail.

2d. The next point was to decrease the normal destru
wear. Breaking down did not occur, and lamination coul
cur in the product of a fusion process. The first, and very
suggestion was to put as much metal as possible into the he
out robbing the web and flange, and impairing the rail as
These points will be considered farther on.

Having as much metal as possible in the head, what pr
and shape endure best, reference also being had to the we
rolling stock? A wide head theoretically reduces the pres
square inch, of the wheels. But on account of the slight c
the wheels, it has been observed that their actual foot-prints
three-quarters to one inch wide, while those wheel-treads w
worn hollow do not take a full bearing on a wide head. If
is wide, it must be thin, with a given weight of rail, so tha
presents less surface and hence a higher rate of flange wea

* Buffalo, Corning and New York Railroad, 1858.

greater variation in the gauge of the track. The head must be wide enough to give ample bearing to the fish-plates, otherwise they are soon worn to such shape that they cannot be kept tight. Exactly the best width of head for a given weight of rail can hardly be determined, but the experience of a decade has convinced experts generally, that for 56 to 70 pound rails, it lies between 2¼ and 2½ inches. Rail designers have, therefore, respectively adopted every possible fraction of this undetermined quarter of an inch.

The exact contour of the head is very important. In 1874 Mr. Chanute, Chief Engineer and Assistant General Superintendent of the N. Y., L. E. and W., then the Erie Railway, observed that rail heads rounded to a small radius wore the wheels out of their normal shape at the junction of the flange and the tread, into a more nearly right angular shape which was obviously less strong and less safe. It was also obvious that the greatest wearing surface, and hence the least rate of wear, would be secured by giving the side of the head such a shape originally, as the wheel would give it by wear. Mr. Chanute then made a large number of templets of worn rails and of worn tires and wheels. In Plate II, Fig. 1 shows the section of a new wheel, and Figs. 2 and 3 show the extremely differing forms after wear. Figs. 4, 5, and 6 illustrate locomotive tires in the same way; the angle is more open than in case of wheels, because the lateral play of tires is greater. From all these templets Mr. Chanute took a mean line, which he adopted as the shape of the head.* Another advantage of this shape is, that with a given weight of metal it widens the fish-plate bearing. As we have observed, the "Chanute" head has been generally adopted, although with slightly varying angles, of course, for 62 per cent. of the 119 standard rails.

3d. The width and shape of the head having been provided for, how much metal can be spared from the web and flange to deepen it, and how shall the remaining metal be disposed? The rail is now to be considered as a beam, and as a bearing to transfer the vertical and lateral strains to the sleepers. It is obviously impossible to determine the exact proportions which are better than any others, because the conditions of use vary almost infinitely; but so nearly the best form for average use has been determined by practice, that no one can prove it not to be the best.

I. The web and base of the rail have been pared down to meet the conditions of the beam, until further reduction would impair

* See a foregoing note regarding the earlier use of this form of head.

their safety. It fell to me to point out, in a discussion of this subject before the Society of Civil Engineers, that permanent rupturing strains would be left in a rail of which the flange was so thin that it came out of the finishing groove at a little higher temperature than "black hot," while its heavy head finished at a bright red. Engineers generally who were starting on excessively thin flanges, thickened them to meet this circumstance of manufacture. The minimum thickness of the edge of the flange for rails above 56 pounds is $\frac{1}{4}$ inch the thickness of the flange where it joins the stem is from $\frac{5}{8}$ to $\frac{7}{8}$ inch or that which will give an angle for the fish-plate of about 12° The reason of this will be further considered.

The width of base must be so great that the rail will not turn over, and will not cut into the sleepers. Mr. Sandberg's rule for sleepers, 3-feet apart centres, is to make the width and height the same, except that in the lighter sections the proportion of height is increased. In the best American practice, with sleepers 2-feet apart centres, the base and height of rails are usually the same. A 4-inch base, with $4\frac{1}{2}$-inch height, is the largest deviation from this rule. The $6\frac{3}{8}$-inch base of the $4\frac{1}{2}$-inch rail of the Metropolitan Railway in London, is a singular departure in the other direction.

II. The web of the steel rail has been pared down until it runs in the twenty-two 56-pound patterns, from 13 to 20 thirty-seconds, and in the thirty 60-pound patterns, from 7 to 10 sixteenths of an inch. But no web of any of the current patterns has broken down from being too thin. Whether or not a 6 1th should be added or removed, no man can say; nor is the question of farther variation of any importance, except to the immortals before mentioned.

III. The foregoing proportions having been settled, the question is: How much of the remaining metal shall go into height of web and how much into thickness of head? To perfect the rail as a beam, so much of it should go into the web as to at least double the standard height, because the stiffness of the beam increases as the cube of the height. But it has been ascertained that with the best existing type of roadbed, $5\frac{1}{2}$-inch rails wore out more rapidly than 4-inch rails of the same quality. The reason is obvious: the high rails were too rigid; the lower rails yielded slightly under the load. Dr. Dudley graphically describes wear as the breaking or mashing of the infinitesimal teeth which form the surface of the rail. We may regard the wheel as a projectile which breaks and mashes the teeth. Its destructive effect is as the square of its velocity; t

elasticity of the rail increases the time of impact, and so decreases the power of the blow.

As the tread of the rail becomes a more and more perfect plane by means of better manufacture and roadbed, the stiffness of the rail may be increased, and no doubt will be increased to carry heavier loads per wheel. With good ballast of the present type, and sleepers 2 feet apart centres, it has been found that a well-proportioned rail of about 4½ inch height, will carry the present loads of 5 or 6 tons per driving-wheel to the best advantage. The Great Western Ω-rail, still used, is the worst form for stiffness.

The rule for spacing sleepers in a country where they are comparatively cheap, is to leave just as little space between them as will allow the convenient tamping of ballast. There is great convenience in the even number, 2 feet, and it cannot be proved that it is not as good as 2 feet and a quarter of an inch, which some rail tinker would no doubt have specified, if it had occurred to him.

Iron and steel sleepers, so largely used in Germany and elsewhere, and especially the longitudinal system, will no doubt modify our permanent way, in all departments, at a not distant day, but we shall have time to enjoy any improvement of our present system.

Having thus determined all the proportions except the thickness of the head, we find that rails of 60 to 72 pounds per yard, may have heads of 1¼ to 1½ inch mean thickness (see Table I), which will last, under average traffic, until new conditions of roadbed, load, and manufacture shall have indicated farther improvements in the weight and proportions of steel rails. It probably would not pay, considering the interest account and probable improvements, to secure longer wearing capacity, except in rails for specially severe service.*

IV. What determines the angle of the underside of the head to hold the fish-plate? If the plate could bear against horizontal surfaces it would not be forced out laterally by the load; but it could not be properly fitted by rolling; its play would rapidly increase and could not be taken up. Mr. Chanute experimented in this direction also, and found that with angles above 15° the plate was loosened by the stretching of the bolts; this relieved the pressure and friction of the plate against the nuts and allowed them to turn. He therefore adopted the angle of 15° under the head. To avoid unnecessary metal in the flange, he made its angle 12°. With the angle plate,

* Table II gives particulars and capacity of Sandberg's sections. His standard 60-pound steel rail is shown on Plate II.

(see Plate II), which can hardly be put on wrong side up, the difference in the top and bottom slopes can do no harm. Mr. Sandberg specifies 11° at both top and bottom for heavy rails,* and 15° for light rails.

Speaking of the angle fish-plate (a good specimen of which is shown with Mr. Sandberg's 60-pound rail)—while recent inventors of this excellent device are disputing about their priority, I call your attention to an engraving reproduced from Colburn & Holley's "European Railways," published in 1858, and entitled, "58-pound rail with Adams's bracket joint." (See Plate II.) This form of fish-plate was invented by the late William Brydges Adams, of London, about 30 years ago. It was first introduced here, and greatly improved in form by the Bethlehem Iron Company. I also venture to remark that I designed the rail shown with it 24 years ago. It rather differs from the patterns current at the time, the worst example of which is shown by the 84-pound rail on Plate II. It was intended to be made of the best reheated soft iron, which with thin and hence elastic heads, had been proved to break down least and to wear best. The flange was made a little thick, so that it could be rolled out of tough, red-short iron.

Fourth. Having thus observed that the proportions and contour of the majority of the standard patterns were determined by scientific methods, and that no new departure is necessary in the present state of the art, we are confronted with the final question: How are 60 or 70 patterns of rails, all of them illustrating the established principles, to be reduced to the few patterns, which by universal adoption, each for its own character of service, will enable the great economies we have considered to be realized? The reform is certainly not to begin by making a new set of patterns. Better roadbeds, steel sleepers, heavier wheel loads, and improved adaptations of steel, will determine new patterns in due time.

For the present needs of all concerned, the obviously reasonable and the only practicable solution is for railway companies to fix on the, say 10 patterns, each of different weight, from about 30 to 7 pounds, which most completely embody the settled principles of steel rail proportions, with reference also to the extent to which such patterns have already been adopted. For instance, it would not be reasonable to ask the many companies who have adopted the most used and good 60-pound pattern (see Plate I), to inaugurate refor

* Table III gives particulars of Sandberg's rail fastenings.

by changing to a better pattern. No railway company which has a good pattern likes to change; each insists that it has as much right as another to perpetuate its own pattern. In so far as railway managers treat the subject on these narrow grounds, no reform can come.

Guided by the principles we have considered, I venture to suggest the 10 patterns shown on Plate I, and selected out of the 119 current patterns, as standards for steel rails. I have thought it best not to complicate the matter by stating who designed these rails, or who rolls them or who uses them. These facts can be found out by those who need them. The only important facts are that these patterns, on the average, embody more nearly the established principles, and are more largely used than any other set of 10 modern patterns.

No expert whom I have consulted in the matter thinks 10 patterns too few; some say that the 67 pound between the 60 and the 72 pound is enough, and that the 63 and 65 are unnecessary. The 63 and 65 are, however, largely used, and I am sure that steel-makers will not object to stocking rails of 10 patterns, as far as may be necessary, if railway companies will only agree on them.

To start the reform—if a considerable number of companies who use, say a 57 to 61 pound rail, or whose traffic a 60-pound rail would suit, would agree on a good 60-pound pattern which is most used—if they would only agree to adopt it, say for two years' orders, rail-makers could and would gradually begin stocking this standard rail when orders were slack, in the certainty of selling it at a fair price when any of these roads might want rails. Rail-makers would take the risk of changes, as under such a system, changes would be made, not by capricious individuals, but by a convention of experts; and they would be foreshadowed by discussion and consultation. The system once inaugurated would be tested; attention would be drawn to its advantages, and it would inevitably become general.

The cost and trouble of changing the pattern of *steel* rails is not so very formidable, when closely considered, in view of one fact,—steel rails wear so uniformly, under similar conditions, that long sections of track can be renewed at a time, thus requiring but few special fastenings where the pattern changes. With iron rails, especially those bought at the lowest price, the difficulty would be very largely increased.

Fifth. It may be said that uniformity in patterns is just as necessary for iron rails, which are still largely used and to be used. If the best iron rails were used, there would be little difficulty in determining standard patterns; but the *best* iron rails will cost more than

steel rails. I do not feel equal to the consideration of those varieties of iron rails which are laid by speculators, just to get a road running and its securities unloaded.

Sixth. Rail fastenings would also have to be uniform, to a certain extent, for each pattern. Rail-makers could not stock unfinished rails and then get them all back into the mill for drilling and slotting, thus interrupting current work. Fish-plates of all types may be used, so long as their bearings fit the standard rail.

The foregoing considerations about uniform rail patterns apply equally to fish-plates, and need not be repeated. The present diversity of patterns is perfectly unnecessary and wasteful.

It should at least appear that the size and pitch of fish-bolt holes might be agreed upon, and yet they differ to a degree which is ridiculous. In 21 patterns of rails made at one mill, there are 6 different diameters of hole (from $\frac{3}{4}$ to $1\frac{1}{16}$ inch.); there are 10 different distances apart of holes (from 4 to 6 inch.); and there are 14 different distances of the first hole from the end of the rail ($2\frac{1}{8}$ to $3\frac{1}{4}$ inch.) For one pattern, the distance is two and thirteen sixty-fourth inch. To think that the mind of man can hit perfection in spacing fish-plate holes within the 64th of an inch, is almost appalling.

It would be impossible within the limits of this paper, which I fear is already wearisome, to fully discuss rail fastenings. It should be obvious to every one that the angle-plate has every advantage over the plain splice as a means of holding the rail vertically and laterally, and especially as a means of preventing the creeping of rails without starting fractures in them by nicking their flanges. Table III gives Mr. Sandberg's specifications for fish-plates and bolts. It seems proper in this connection to recognize Mr. Sandberg's important contributions to good permanent way, during the last twenty years, by means of careful experiment and observation and by means of a system of inspection which, in its theory and its difficult administration, is fair to both the makers and the users of rails.

In conclusion, let us very briefly review the ground we have traversed.

No expert will deny, I think, that about 10 weights of rails will just as perfectly meet the requirements of railways as the 27 weights which are now standard, and that some one pattern of any given weight is better than many patterns, for instance, than the 29 other standard 60-pound patterns.

The multiplication of patterns is a source of expense and trouble

to rail makers in getting up new rolls and in delays while changing rolls. But it is a source of far greater expense to railway companies, chiefly by preventing the stocking of standard rails, which would check fluctuations in price and prevent excessive prices. Fluctuation in output also wastes capital, plant, and time, for all of which railway companies must pay in the long run.

There were two principal causes of the multiplication of rail patterns. The first was the natural result of adopting for steel the patterns of iron rails, which provided for every variety of defectiveness peculiar to iron, and of adapting patterns to the various grades of steel until a standard grade was determined. The other cause was the unreasonable egotism and the narrow and trifling considerations of certain railway officials.

Other railway officers, however, have in a scientific manner determined the proper proportions and contours for steel rails, and they have determined exact patterns which are so nearly correct that they cannot be proved to be incorrect. The majority of railway companies have adopted the proportions and contours, but the patterns are still very numerous.

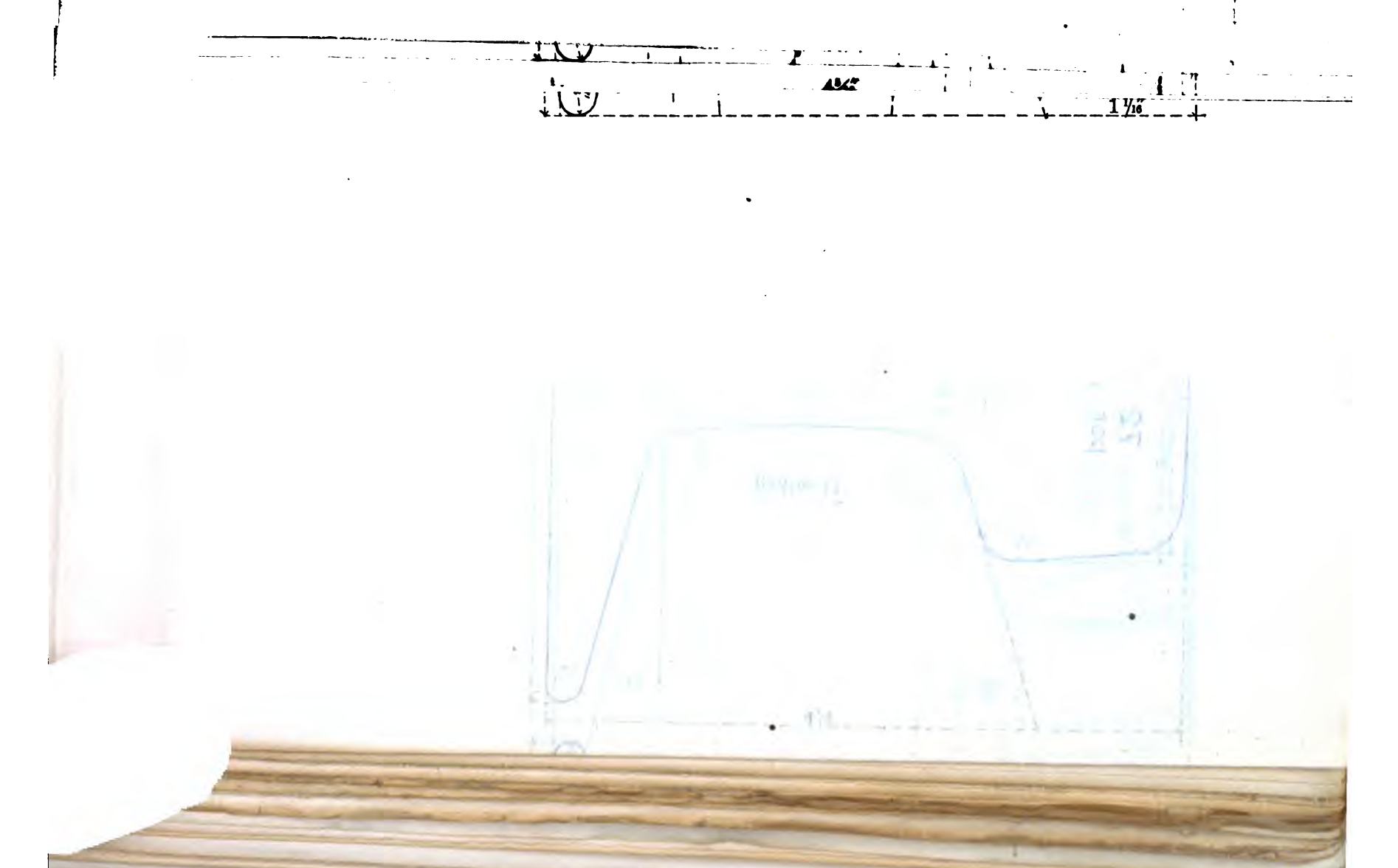
The obvious way to reduce the existing many to the few necessary patterns is to adopt, for each of the necessary weights, that existing pattern which most nearly conforms to the principles which have been established, and with reference also to the extent of its present use. The patterns shown on Plate I, are proposed as possibly the best that can be selected.

Rail fastenings must be uniform to a certain extent, but this reformation does not present serious difficulties.

Meanwhile improved roadbed, heavier wheel weights, and new adaptations of steel will provide the elements for improved rail patterns, and these will be devised in a scientific manner by that class of railway managers which has so largely improved the forms of steel rails.

Weight of rail per yard.	SHAPE HEAD. Rounded side of head.	Straight side of head.	Bevelled side of head.	Number of patterns.	Maximum *height.*	Minimum *height.*	Difference in *height.*	Maximum width of *base.*	Minimum width of *base.*	Difference in width of *base.*	Maximum *thickness of head.*	Minimum *thickness of head.*	Difference in *thickness of head.*	Maximum *width of head.*	Minimum *width of head.*	Difference in *width of head.*	Maximum *thickness of stem.*	Minimum *thickness of stem.*	Difference in *thickness of stem.*
30			2	2	3	3	0	3 1/2	3 1/2	1/8	7/16	2 7/16	1/2	1 1/2	1 1/16	1/16	3/8	3/8	1/2
35			2	2	3 1/4	3 1/16	1/16	3 3/8	3 1/2	1/4	7/16	3/8	0	1 7/16	1/4	1/8	3/8	3/8	1/2
36	1			1	3			2 7/16			1 1/16			1 1/16					
40			5	5	3 1/8	3 1/4	1/8	3 1/4	3 5/16	1/16	1 1/16	3/32	1/32	1 1/16	1 1/16	1/8	1/4	1/4	1/8
46	1			1	3 1/8			3 1/16			1 1/16			2 1/16					
50	3		6	9	4	3 1/16	1/16	4	3 1/2	1/2	1 1/16	1	1/16	2 1/8	1 1/16	1/16	3/32	3/32	1/8
51			1	1	4			3 3/4			1 1/8			2 3/16					
52		2	5	7	4 1/4	3 1/16	1/16	4 1/16	3 1/16	1/16	1 5/16	1 1/16	1/16	2 1/16	2 1/16	1/16	3/32	3/32	1/16
52½		1	2	3	4	3 1/8	1/16	4	3 3/4	1/4	1 5/16	1 1/8	1/16	2 5/32	2 3/32	0	3/32	3/32	3/32
53		1	2	3	4 1/8	4	1/8	3 3/4	3 3/4	0	1 1/16	1 1/8	1/16	2 3/32	2 3/32	1/16	3/32	3/32	0
55	1			1	4			4			1 3/16			2 5/16					
56	4	1	17	22	4 1/4	3 1/16	1/16	4	3 3/8	1/8	1 1/8	1 1/16	1/16	2 1/8	2 1/8	1/4	3/32	3/32	3/32
56½			1	1	4			4			1 1/4			2 3/16					
57	1		1	2	4 3/16	4	1/16	4	3 3/4	1/4	1 1/4	1 1/16	1/16	2 1/4	2 1/16	1/16	1/16	1/16	1/16
58	3		5	8	4	4	0	4	3 3/4	1/4	1 1/4	1 1/16	1/16	2 7/16	2 1/4	1/16	1/2	1/2	1/8
59		1		1	4 1/4			3 3/4			1 7/16			2 1/4			1 7/16		
60	14	4	12	30	4 3/16	4	1/16	4 1/8	3 3/4	1/8	1 5/16	1 1/16	1/16	2 1/2	2 1/16	1/16	1/16	1/16	1/16
61	2			2	4 1/4	4		4 1/4	4	1/4	1 5/16	1 1/16	1/8	2 1/4	2 1/32	3/32	1/16	1/16	3/32
62	2		2	4	4 1/4	4	1/4	4 1/4	4 1/8	1/8	1 3/8	1 5/16	1/16	2 3/8	2 5/32	3/32	1/2	1/2	0
62½			1	1	4 1/4			4 1/4			1 3/8			2 9/32			1 9/16		
63			1	1	4 5/16			4 3/8			1 7/16			2 11/32			1/2		
65	1		3	4	4 1/2	4 3/16	1/16	4 1/4	4	1/4	1 1/2	1 1/4	1/4	2 3/8	2 1/4	1/8	1/2	1/2	3/32
66			3	3	4 1/2	4 1/8	1/8	4 1/2	4 7/16	1/16	1 5/16	1 3/16	1/8	2 1/32	2 3/32	1/16	1/32	3/32	1/16
67			2	2	4 1/2	4 1/2	0	4 1/2	4 1/2	0	1 7/16	1 1/4	1/16	2 1/16	2 1/8	0	1/2	1/2	0
69	1			1	4 1/2			4			1 5/16			2 1/32					
72			1	1	4 1/2			4 1/2			1 1/2			2 3/32					
74	1			1	4 5/8			4 3/16			1 5/16			2 5/32					
27	35	10	74	119															

NOTE.—The thickness of the head is taken on a vertical line, half-way between the face of the web and the side of the head.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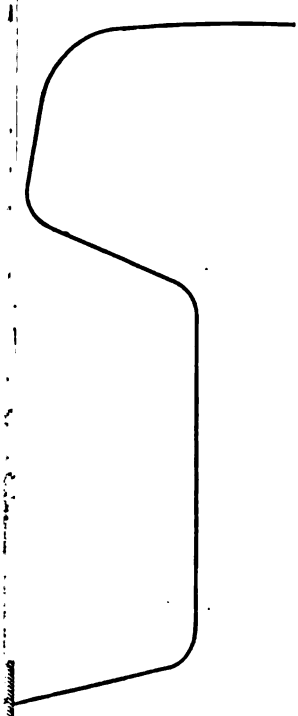
Holl

58 lbs



LEHIGH VALLEY TEN

TABLE II.

Weight, Dimensions, and Capacity of Sandberg's Standard Rail Sections.

Sandberg's standard sections. Weight of rail per yard. Pounds.	Height of rail. Inches.	Base of rail. Inches.	Stiffness. Dead weight in tons on rail-joint, 2 ft. supports, without permanent set.	Maximum load in tons on each driving wheel for ordinary goods engine.
30	3	2¾	3.0	2.0
35	3¼	3	4.0	3.25
40	3½	3¼	5.2	4.0
45	3¾	3½	6.3	4.75
50	3¾	3½	7.3	5.5
56	4	4	8.2	5.87
60	4¼	4¼	9.2	6.25
65	4½	4½	10.2	6.62
70	4¾	4¾	11.2	7.0
75	5	5	12.2	7.25

TABLE III.

Fastenings for Sandberg's Standard Rail Sections.

Rails. 30 and 35 pounds per yard.	Rails. 40 and 45 pounds per yard.	Rails. 50 pounds per yard.	Rails. 56, 60, and 65 pounds per yard.	Rails. 70, 75, and 80 pounds per yard.
Holes in rails. 1″ × ¾″ oval.	Holes in rails. 1⅛″ × ⅞″ oval.	Holes in rails. 1″ × 1¼″ oval.	Holes in rails. 1⅛″ × 1⅜″ oval.	Holes in rails. 1¼″ × 1½″ oval.
2 holes at each end. Centre of first hole 1 $\frac{1}{16}$″ from end of rail. Centre of second hole 3½ from centre of first.		2 holes at each end. Centre of first hole 2 $\frac{3}{16}$″ from end of rail. Centre of second hole 4¼″ from centre of first.		
Holes in plates. ¾″ diameter.	Holes in plates. ⅞″ diameter.	Holes in plates. ⅞″ diameter.	Holes in plates. 1″ diameter.	Holes in plates. 1⅛″ diameter.
Fish-plates 13″ long. Four pear-shaped holes. 3½″ between centres in each plate.		Fish plates 18″ long. Four pear-shaped holes. 2 $\frac{1}{4}$″ from centre of first hole to end of fish. 4½ from centre to centre.		
Pear-shap'd bolts $\frac{5}{8}$″ diameter.	Pear-shap'd bolts ¾″ diameter.	Pear-shap'd bolts ¾″ diameter.	Pear-shaped bolts ⅞″ diameter.	Pear-shaped bolts 1″ diameter.

SHOCKS ON RAILWAY BRIDGES.

BY JOHN W. CLOUD, ALTOONA, PENNSYLVANIA.

THE delivery of blows upon roadway structures by the locomotive engine at high speed, although long recognized, has, perhaps, not been as generally understood in severity, relation to speed, and cause as is desirable in matters of such importance. Some points of explanation, with illustrative diagrams, are, therefore, submitted to your attention, preparatory to a note on "Steel for Bridges," also submitted.

In order that a locomotive may run at high rates of speed with-

out fore and aft irregularities of motion, it is necessary that counter-weight be added to the driving-wheels, not only for crank-pin hub, crank-pin, and weight carried thereon, but also for the weight of those parts which move only in a horizontal direction, viz., piston, piston-rod, cross-head, and that part of main rod carried by the cross-head. This additional counterweight is usually divided equally between all the driving-wheels, and, in the case of a Pennsylvania Railroad standard locomotive, class "B," it requires an addition of counterweight to each wheel equivalent to 300 pounds, at a distance of 12 inches from the wheel centre, to properly control the motion. This brings correspondingly too much counterweight vertically, but it does not result in objectionable disturbances because the forces are resisted by the road-bed in one direction and by the weight of the machine in the opposite direction.

In locomotives for low speed only, a part of this additional counterweight can be left out without apparent evil results, but in express locomotives it is necessary to use nearly all that the theory requires. From this cause a series of blows results, which we may examine by the aid of the diagram on the accompanying plate (Fig. 2), a little more in detail.

The length of this diagram, from left to right, represents one revolution; the vertical scale is 1 inch = 3200 pounds, and the horizontal line through the centre is a line of normal pressure of one wheel upon the rail; *i. e.*, it is a sufficient distance above an imaginary datum line below, and entirely off the diagram, to represent, on the same scale, the quiescent weight of the wheel on the rail. The speed is assumed at 50 miles per hour, and one revolution is considered commencing when the engine on right side is on its first quarter; that is, when the counterweight on the same side is in its highest position. The curve *a* shows the boundary of the vertical components of the centrifugal force of 300 pounds additional counterweight at a radius of 12 inches for one wheel on the right side of the locomotive, these components being laid down, on a scale of 1 inch = 3200 pounds, from the line of normal pressure, below or above, according as they are directed upward or downward, and so *diminish* or *increase* the load of the wheel upon the rail. It will be borne in mind that this additional 300 pounds of counterweight, if located, as supposed, with its centre of gravity 12 inches from the wheel centre (the same as crank radius), will move *horizontally* at all times with the same rate of speed and in an opposite direction to the parts it is employed to balance; if it is of any other weight it must be placed at a corre-

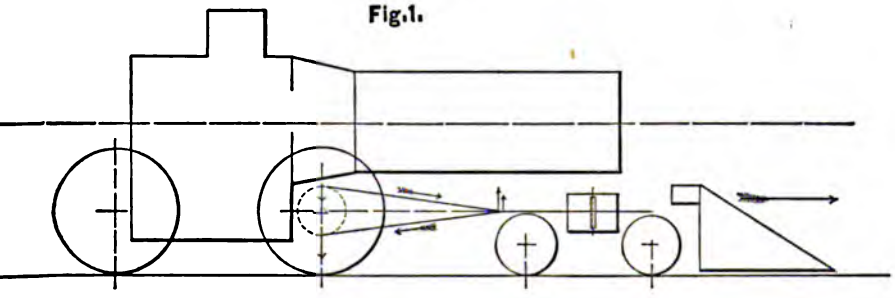
sponding other distance, so that its energy of motion horizontally will at all times be the same; and so, also, vertically, so that the curve given still shows the disturbance of vertical pressures.

The curve *b* shows similarly for one wheel on the left side. This curve is identical with that already detailed, only one-quarter revolution in advance, as the engine on the left side leads the right by that amount. The line *c* shows the resultant of these two curves, and is for two wheels on one axle, but the curves *a* and *b* must be considered individually as to their effects on tires, rails, and roadway structures.

It will be seen that from this cause there results an increase of 6260 pounds above the normal and a decrease of same amount below the normal in the weight of each driving-wheel upon the rail every revolution at the assumed speed of 50 miles per hour, and this cycle is repeated 4¼ times every second, so that it is a series of quick blows of magnitude $2 \times 6260 = 12{,}520$ pounds; it is needless to add that, for other speeds, this will increase or decrease with the squares of the speed, and, at 60 miles per hour, it will be 44 per cent. greater.

Leaving this for the present, let us look at other vertical disturbances from quite a different source, and applicable to the main pair of wheels only, or that pair to which the engines are directly connected.

Fig. 1.



Referring to Fig. 1, which shows some of the outlines and centre lines of Pennsylvania Railroad, class "B," locomotive, it will be observed that when it is running forward the main rod is *pulling* obliquely downward on the crank-pin when the latter is above the centre line of cylinder, and that it is *pushing* obliquely downward on the same pin when the latter is below this line, *i. e.*, except on the two centres, the power of the engine is directed more or less down-

ward on the pin at all times. So far as this goes it increases the weight of the wheel upon the rail by so much as the vertical component of this varying force with its varying obliquity exerted through the main rod.

On the diagram (Fig. 2) again, the curve *d*, above the horizontal line of normal pressure, is the boundary of the vertical components of the force exerted by connecting-rod on the crank-pin during one revolution. This curve lies wholly above the line of normal pressure, except two points which are in this line, because, as already stated, the vertical component, when there is any, is always directed downward in running forward, and therefore increases the pressure on the rail.

In plotting this curve the conditions prevailing in this class of locomotive have been observed, with the assumption that the cut-off occurs at one-half the stroke, and that the cylinder pressure, up to time of cut-off, is 110 pounds per square inch.

The corresponding line *e* shows the same for the opposite main wheel, being one-quarter revolution in advance, as before.

As this vertical force is consequent upon exertion, through mechanism, of a horizontal force in the cylinder, there must be at all times an equal reaction vertically upward; this is by the cross-head thrusting against its upper guide, and so far as this force goes it tends to reduce the aggregate weight of the machine on the rails by just so much as we find it increased at the main driving-wheel at all times. The upward force, however, from the varying location of its point of application, is variously distributed at different times as to its relieving effects from driving-wheels and leading truck-wheels. Disregarding the relief from the rear driver, and supposing it all distributed, for the right side, between the main wheel and the truck, it will be found, in plotting, that the curve *f*, below the line of normal pressure, is the boundary of relieving forces at the main wheel for one revolution, the remainder going to relieve the weight on the truck. The corresponding line *g*, shows the same thing for the left side, and is one-quarter revolution in advance. Taking the resultants of the two opposed forces for each side separately, we have, for the right side, the line *h*, and for the left side the line *k*, while the line *l* is the resultant for both sides. On the assumption above, the main driving-wheels are loaded by this amount at the expense of the truck, through the action of the mechanism. They are really loaded more than the diagram shows, because the relieving action

from the rear drivers has been disregarded as somewhat indefinite in magnitude.

The upward reaction on the guides causes the machine to roll, as is often seen when it is laboring hard at slow speed. If the locomotive runs backward the conditions are reversed and main wheels are relieved, the weight being transferred to the truck, so that the weight available for tractive power is less in running backward than it is in running forward.

This concentration of weight on the main drivers varies only with variation of pressures in the cylinder, and is, therefore, independent of speed except as these pressures are varied in consequence. At high speeds this also assumes the character of quick blows on each side, and, of course, at 50 miles per hour the cycle is repeated $4\frac{1}{4}$ times per second as before.

Considering all these disturbing forces on one main wheel only, for the right side, the curve a shows the disturbance from counterweight and the curve h shows the resultant of disturbing forces from the connecting-rod, while the curve m shows the resultant of the two on a scale of 1 inch = 3200 pounds.

Good practice keeps the counterweight as low as possible, but on express locomotives the disturbances here shown frequently occur at each main wheel and rear wheel respectively at the same time. For each main wheel this is an increase of weight upon the rail of 8350 pounds above the statical weight frequently figured on in designing structures, and this increase is followed by a decrease below the normal of 4250 pounds, making a variation of 12,600 pounds, which, at 50 miles per hour, is repeated $4\frac{1}{4}$ times per second.

For each rear wheel it is an increase of weight upon the rail of 6260 pounds, followed by a decrease of the same amount, making a variation of 12,520 pounds $4\frac{1}{4}$ times per second at the same speed, and these variations on one rail are synchronous; *i. e.*, are going through the same phase at the same time; there is, of course, a slight release of weight from the truck at the same time, but this never exceeds 2600 pounds.

This is, therefore, a series of severe blows, each one directed upon some one point, and it requires but the proper combination of circumstances as to the situation of this point (the location of the other point on same rail being struck at the same time), and the proximity of other heavily loaded wheels to produce the maximum strains upon some member or members of a resisting structure already in a state of oscillation from the regular and successive blows received.

This will account for the necessity of a considerable portion of the factor of safety allowed in such structures as railway bridges, and will also help to account for the failure in service of a certain grade of steel with a factor of safety higher than is successfully allowed with iron in similar structures. (See paper on "Steel for Bridges.")

STEEL FOR BRIDGES.

BY JOHN W. CLOUD, ALTOONA, PENNSYLVANIA.

In 1877 the Pennsylvania Railroad Company removed an old bridge from its line at Duncannon, Pa., built intermediate piers and erected shorter spans of the Pratt truss type, which had previously been in use on another portion of the road. The design of this truss would not admit of diagonals larger than 1⅞ inches diameter, and in order to stiffen the bridge somewhat steel rods were introduced for the main diagonals in the first and second panels, 1⅞ inches and 1⅜ inches diameter respectively. These rods were threaded without upsetting, and by the ordinary formulæ the strains were of the same intensity upon both, viz., 16,000 pounds per square inch with the maximum loading. The other main diagonals in the truss are 1⅝ inches diameter, and of iron.

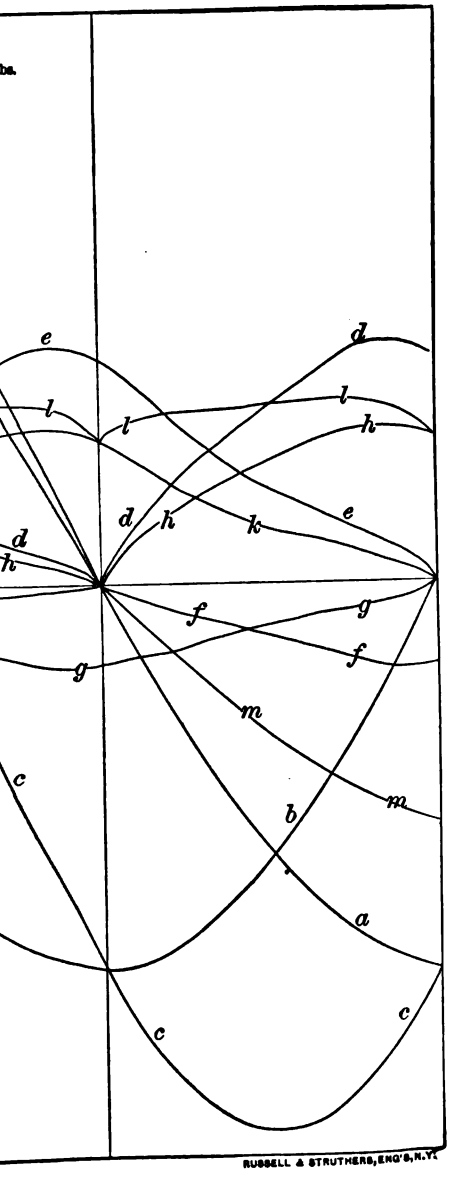
It was specified for the steel rods:

Elastic limit,	45,000 lbs.
Tensile strength,	80,000 lbs.
Elongation,	20 per cent.

The steel was procured without difficulty, and it allowed a factor of safety of 2¾ at elastic limit, while a similar factor of 2½ had for a long time been successfully used for iron.

In the course of three years, from time to time, six of these steel rods broke, three of them being 1⅞ inches in diameter, and three 1⅜ inches in diameter. The broken rods were tested, and three of them analyzed at Altoona to ascertain the cause of failure, and what modifications should be made in the steel for such service. Examination showed that all the rods were broken in detail close under the nut. The threads were well cut and properly rounded at the root.

In testing the rods micrometer screws, reading to .0001″ with electric bell to signal the contact, were attached to the test pieces and by this means the modulus of elasticity and elastic limit accurately obtained.



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Below is representative test:

Modulus of elasticity,	45,000,000
Elastic limit,	42,000
Tensile strength,	85,000
Elongation in 5 inches,	28 per cent.

with very slight variations in the different rods.

Analyses of these rods showed:

	No. 1.	No. 2.	No. 3.
Carbon	.326	.315	.298
Phosphorus	.051	.041	.049
Manganese	1.432	1.418	1.448
Silicon	.052	.033	.043

Iron rods that had given long and successful service with less factor of safety in another locality showed:

Modulus of elasticity,	22,000,000
Elastic limit,	24,000
Tensile strength,	50,000
Elongation in 5 inches,	25 per cent.

No chemical examination was made of these rods.

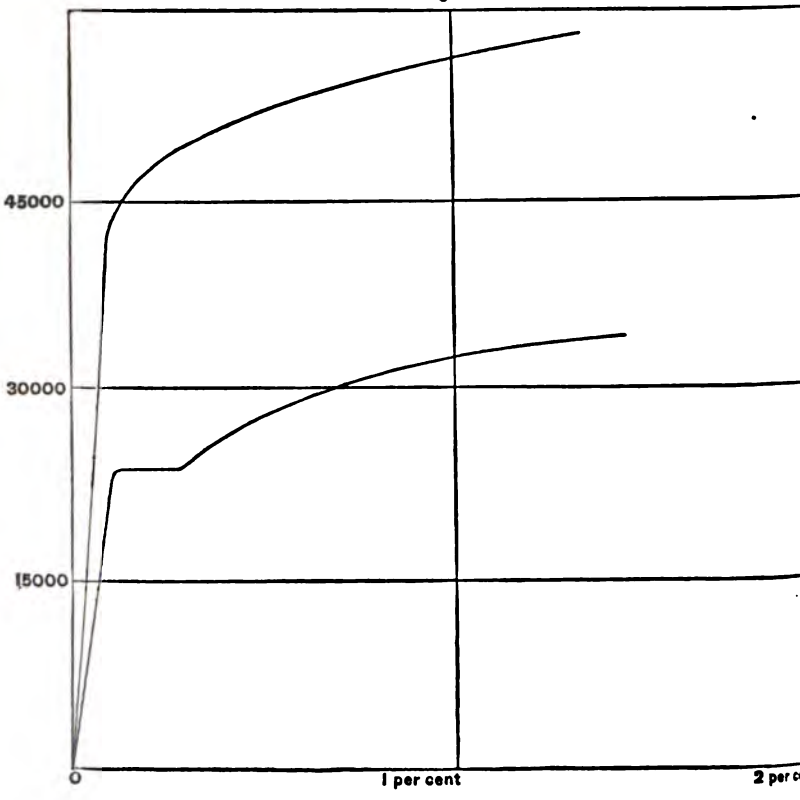
This is a case where elastic limit, tensile strength and elongation are not reliable criteria of the fitness of the steel for the service; the modulus of elasticity, so very important and yet so generally neglected, rendering it unfit without showing any deficiency in the specification figures.

That this great stiffness of the steel was the cause of the failure can easily be made apparent. A bridge of this type is never accurately mechanical in its construction, the angle blocks are unfinished castings bearing upon unfinished chords, and the surface against which the nut has its bearing is not accurately at right angles with the rod. Even if it were made so, it would not remain accurately in place throughout the oscillations set up in the truss by the continual hammering of express locomotives in passing. And with the bearing on one side of the nut, more or less, the heavy and frequently repeated shocks from the locomotive bring greater strains upon one side of the rod than was intended for the whole section, and cause fracture to develop in that side most heavily strained,

because the steel is too stiff to yield sufficiently to the bending action, and to accommodate itself to the uneven bearing, as the iron does. This is not because it is steel, but because it is the wrong grade of steel for the purpose.

Plotting the tensile tests given of the steel and iron to a point beyond the elastic limit shows in that region as in diagram, Fig. 1.

Fig. 1.



Diagram, Fig. 2, shows a quite similar result obtained automatically on Professor Thurston's torsion machine, only that part of diagram near elastic limit being copied.

These diagrams both show very clearly why the iron will withstand a service of this kind and the steel will not, for in addition to the greater stiffness of the latter, as shown on the diagrams, the iron, as is well known, takes more readily a permanent set also, and therefore sooner accommodates itself permanently to the unmechanical workmanship always existing in such structures, and allows the

Fig. 2.

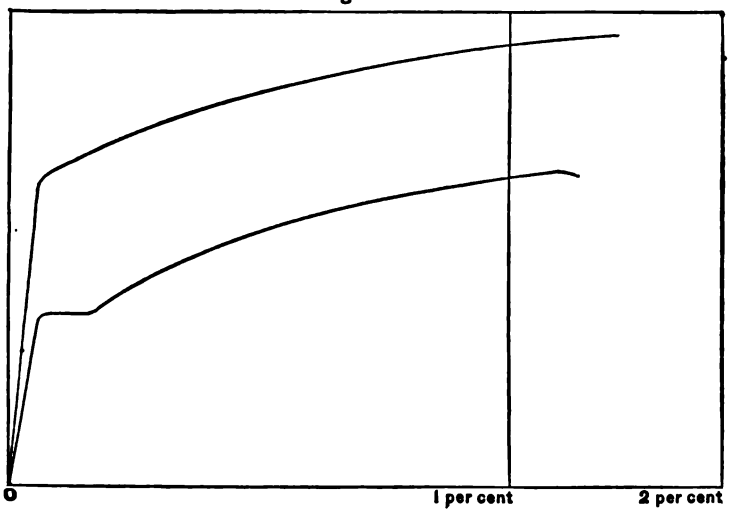
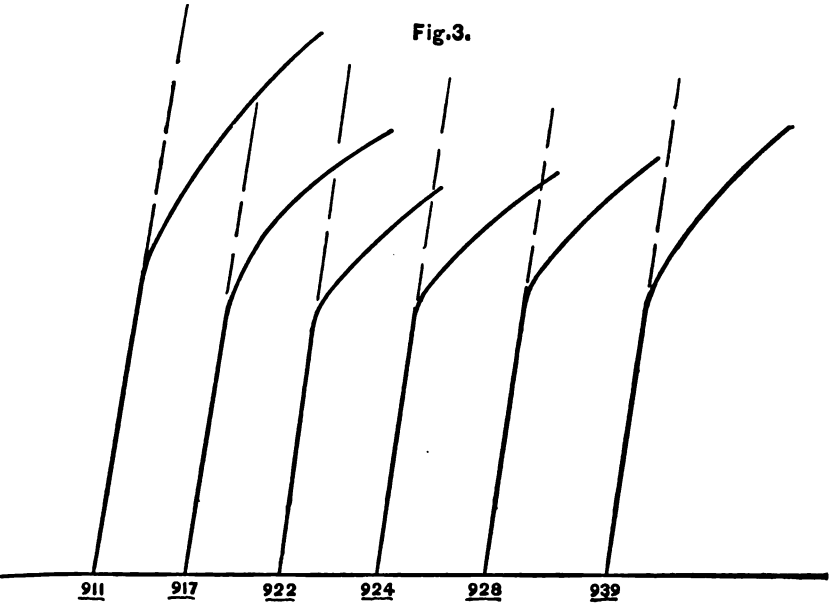


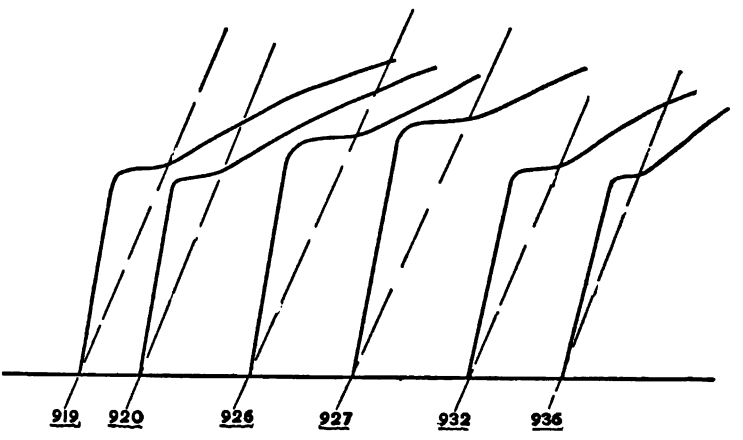
Fig. 3.



No.	Angle.	Carbon.	Phosphorus.	Manganese.	Silicon.
911	9°	.618	.154	1.044	.039
917	9°	.423	.127	.708	.083
922	7°	.428	.109	.870	.038
924	7°	.388	.123	.806	.059
928	9°	.428	.142	.564	.042
939	8°	.579	.115	.718	.036

nut to find its proper bearing. Had the modulus of elasticity of this steel been between 25,000,000 and 30,000,000 instead of 45,000,000, even had the elastic limit and tensile strength been reduced 10,000 pounds and 20,000 pounds respectively in consequence, it would probably have withstood the same service successfully with a factor of safety of 2 instead of $2\frac{3}{4}$ at elastic limit. Rods of the same size but of lower grade of steel are now being made to put into this bridge. Iron can be rendered less fit for this kind of service by being rolled too cold, and the same is probably true of steel, but the chemical content must be altered in this case to produce the requisite pliability. This can best be done by a reduction in the manganese, if

Fig.4.



No.	Angle.	Carbon.	Phosphorus.	Manganese.	Silicon.
919	22°	.247	.041	.344	.023
920	21°	.293	.063	.326	.039
926	23°	.211	.145	.352	.033
927	23°	.187	.131	.320	.049
932	22°	.269	.047	.372	.026
936	20°	.394	.035	.288	.038

the indications as to chemical content and torsion test in the Figures and Tables 3 and 4, selected as representative from the sixty-four samples of steel rails on which Dr. Dudley's paper, read at this meeting, is based, can be considered reliable. For by referring again to the iron rod on the diagrams Figs. 1 and 2, and to the diagram Fig. 4 of steel rails, to the considerable elongation which occurs at the elastic limit without any increase of load, it will be

seen that in the iron and the soft steel, unlike the hard steel in Fig. 3, there is a considerable elongation at the elastic limit without any increase of load. This is not taken into account in estimating the modulus of elasticity, so that it may be possible to have a high modulus, if this feature exists at the elastic limit sufficiently marked, without the steel being unfit for such service; but as will be seen it is necessarily a low steel at all events.

CAN THE MAGNETISM OF IRON AND STEEL BE USED TO DETERMINE THEIR PHYSICAL PROPERTIES?

BY WILLIAM METCALF, PITTSBURGH, PA.

ONE of the first questions that naturally occurs to one who handles steel is, "Why does steel harden?" To answer this question the chemist and physicist have devoted much thought and experiment, and while they have enriched our store of knowledge of the nature and composition of steel, it cannot be said that they have yet solved the problem involved in its hardening.

In this communication I desire to direct attention to a line of investigation yet new, in the hope that it may receive the attention of those who have the time and ability to pursue it. I refer to *magnetism.*

There are so many parallels between the action of magnetism on iron and steel and their behavior under different processes of manipulation that it would seem as if there must be some connection between the forces at work in the different cases, if, indeed, there be not an identity of force in all of these cases.

Magnetism, as we know it, may be merely the visible manifestation of forces, which may serve as a guide to lead us to an exact knowledge of the structure, the strains, and the resistances with which we have to deal in iron and steel.

If a magnet be brought close to a pile of iron filings, the little pieces of iron will fly to the magnet and attach themselves to it, with their longer axes lying in the direction of the force. If molten cast iron be poured into an iron mould,—a chill,—the iron upon crystallizing will form needlelike crystals, with their long axes normal to the surfaces of the mould. If the iron is at the proper temperature and the quantity small, compared to the mass of the mould, the whole of it will be chilled, or set, in the hard needlelike crystals

just mentioned. If the mass of molten iron is comparatively large, only a part of the mass, next the surface will be chilled, and near the inner edge of the chilled part will be found numerous specks of graphite, which have the appearance of having been driven out in the operation of chilling. The mould in this case may not be a magnet, but it acts like one.

Chilled iron, in resistance to compression or abrasion, has enormous strength, as may be seen by the thousands of miles run by chilled car-wheels, or in the case of the hammer-die, which will resist millions of blows upon steel hammered until it is black and very hard.

The same structure may be observed in ingots of steel when they are in the condition which the melters call "scalded,"—in reality when they are chilled. A better name, perhaps, and one much in use, is "polarized ingots," and for the present we will use this term. A polarized ingot looks very much like chilled cast iron, and like it breaks very easily along the planes of cleavage, parallel to the axes of the crystals.

Like chilled iron, polarized steel may be reduced to an entirely amorphous arrangement of crystals by a good red heat, continued for some hours, to give the crystals time to rearrange or disarrange themselves. Unlike chilled iron, polarized steel is not hard, offers no great resistance to any strains, and has no industrial value. This is due, doubtless, to an insufficiency of carbon.

There is a similar, but not an identical, polarization of crystals, dispersed through the mass of steel ingots, which appear when there is a certain quantity of carbon present; but above and below a small range of carbon, this polarization disappears or changes its character. I shall refer to this latter.

If pieces of soft iron or of mild steel be heated and quenched in water, they will not harden. If the same pieces be magnetized they will not retain the magnetism. If the iron be converted into very hard blister steel, and worked into shear steel, it will harden, and then, if magnetized, it will retain its magnetism; and the mild steel could be converted in the same way. If a permanent magnet be heated it will lose its magnetism as the temperature is raised, and regain it as the temperature is lowered. If the magnet be heated to a white heat, or to a high yellow heat, it will lose its magnetism entirely, and also at the same heat the steel will lose its temper.

If pieces of steel of, say, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00, and 1.10 per cent. carbon, be sent to a magnet maker for trial he will

invariably select samples containing about 0.90 carbon as giving the best results. If tables of physical tests of steel be examined, and notably Kirkaldy's tests of Fagersta steel, the highest resistance to all strains except compression will be found at about 0.90 carbon. If the polarization before referred to as not due to chilling, be examined, its most perfect development will be found at about 0.90 carbon. If the great majority of all steels adapted to the greatest variety of uses, and giving the highest results as to strength, retention of a keen edge, etc., be examined, they will be found to be about 0.90 carbon.

A bar of hardened steel when magnetized retains its magnetism indefinitely; and the magnet may be loaded far beyond its original capacity by the addition of a small weight day by day, but this increased capacity is lost immediately if the load is removed. Similarly the elastic limit of iron or steel may be raised by repeated straining between the limits of elasticity and rupture, as has been proved by Professor Thurston; but he has not shown that there is any reliable permanent increase of the limit of elasticity which would justify an engineer in taking advantage of this apparent increase of strength.

There seems to be a connection between paramagnetics, diamagnetics, and the character of alloys of iron containing them. For instance, we have among the paramagnetics: iron, nickel, cobalt, manganese, chromium, titanium, cerium, palladium, platinum, osmium, oxygen. Among the diamagnetics we have bismuth, antimony, tin, lead, mercury, gold, silver, zinc, copper, glass, phosphorus, sulphur, mercury, jet. As far as ordinary experience or the records teach us, every one of the above paramagnetics, except oxygen, will form useful alloys with iron; and, on the other hand, not one of the diamagnetics named, except carbon, forms any useful alloy, and most of them are rank poisons in steel.

An investigation by means of magnetism seems justifiable on other grounds. If a piece of steel be powerfully magnetized, it is found to be lengthened in the direction of the force, and reduced in section in a direction perpendicular to the force. Here then is a change of form, but no change of volume; in other words, we have extension of length and reduction of area, or the exertion of a force which, measured in the ordinary way on a bar one inch square, would represent the application of a strain of something over fifty thousand pounds.

If a bar of steel be magnetized suddenly, a clink is heard at the

beginning and the end of the operation. Who will assert that a bar might not be actually ruptured in this way as well as by awkward management in quenching it to harden it?

A magnetic needle is said to be in common use in Woolwich Arsenal for the detection of flaws in iron and steel, and a very ingenious instrument was described before this Institute for determining the carbon in steel by means of magnetic deflections.* The latter instrument may not be exact enough in carbon determinations, but it might be made very useful in helping to determine total quantities of iron and substances not iron, or, possibly, to determine the totals of paramagnetics and diamagnetics present in a given specimen.

Ingenuity and research might point out many more comparisons, but surely enough has been shown to justify the assertion that it would be well worth while to investigate the subject thoroughly. If a little needle will point out every defect in the interior of a huge forging, if a delicate pendulum will indicate quantities of iron and substances not iron, if an obedient force held in a little instrument in one hand may be made to produce an effect in a piece of steel passed over it by the other hand equal to a strain of more than fifty thousand pounds, who will say that the great Emery testing machine may not some day be declared a very cumbersome and unnecessary piece of apparatus? Is it not possible that the engineer of the future will carry with him in a gripsack all of the tools necessary to tell him what he needs to know about the material he is getting for his structures?

The phenomenon of "consequent points" ought not to be overlooked, as it is more than probable that they are due either to internal defects or injurious local strains.

In conclusion, I have only to repeat the hope that the suggestions and analogies to which I have called attention may be fruitful in other and abler hands.

A NEW BOTTOM FOR BESSEMER CONVERTERS.

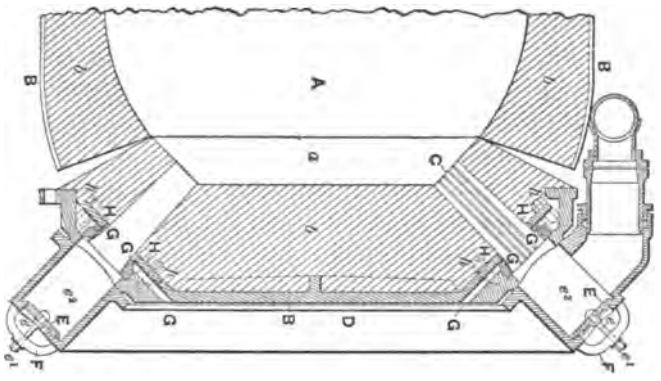
BY CHARLES F. MANNESS, SCRANTON, PA.

In the great increase of product which has been accomplished in the American Bessemer plant, through improvements in machinery and refractories, and by more perfect skill in their manipulation,

* Transactions, vol. v, 881.

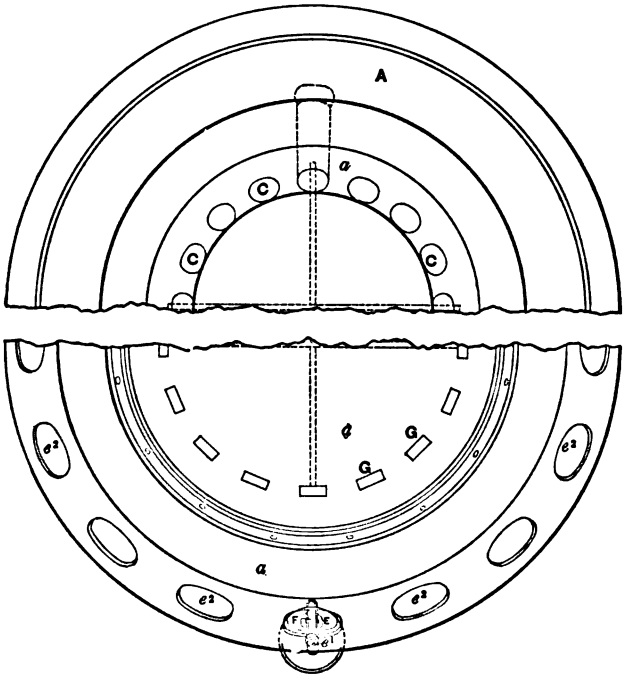
the converter bottom, in this country, has undergone no essential change.

Fig. 1.



Its modifications and improvements, although not unimportant, have consisted, as far as the writer is aware, of merely changes in

Fig. 2.



the size, nature, and position of the joint connecting it to the main body of the converter. The tuyeres have always been vertical.

The manner in which these bottoms wear indicates that the metal when subjected to blast is thrown into small but powerful eddies, encircling each air-jet. The tuyeres are thus worn away, while the solid part of the bottom is yet comparatively good.

This fact suggested the setting of the tuyeres in an inclined position and leaving the bottom solid. This construction has been adopted by Mr. John O. Stanton and myself in the converter bottom to which your attention is asked.

It is so constructed as to be applicable to any converter. The joint is a little above the top level of the cast-iron ring which forms the bottom. Each tuyere stands, when blowing, at an angle of about 45°, entering the vessel in the side wall next to the solid surface of the bottom, and injects the air in an inclined direction. The cuts which accompany this description will, I think, explain themselves.

Fig. 1 is a central vertical section through the lower part of a converter with this bottom attached. On the right-hand side is shown a tuyere in position. Fig. 2 is duplex. The upper half is the bottom as seen from above, the lower half as seen from below.

In working out the idea of the angle tuyere I have introduced some things which I know will be of great advantage in practice, such as a port-hole and hand-hole for each tuyere, etc., but I will not take time to describe them, as they may not be new to all.

I think that the horizontal motion given to the air will keep it longer in the metal, and that a given volume of air will do more service by being more thoroughly consumed, and thus shorten the blow. The tuyeres ought to last longer, as the falling metal will not have as good a chance to work on the angular as on the vertical tuyere; and as the solid part of the ordinary bottoms last much longer than the tuyere part, I think a bottom entirely solid will last a great many heats.

I hope at our next meeting to be able to report a practical test of this bottom which I intend to make at Scranton.

THE INDUSTRIAL SCHOOL FOR MINERS AND MECHANICS, AT DRIFTON, LUZERNE CO., PA.

BY OSWALD J. HEINRICH, PRINCIPAL.

AT the Baltimore meeting of the Institute in February, 1879, Mr. Eckley B. Coxe, then president of the Institute, called attention in his address to the subject of Secondary Technical Education, and

gave an outline of a scheme for a school for boys, which it was intended to start at Drifton, Pa., on the general plan of the Steigerschulen of Germany. This school was first opened on May 7th, 1879, when twenty-nine applicants for admission, from 12 to 24 years of age, were examined. Of these eleven were admitted, the others being considered either too young or too deficient in primary education to profit by the instruction. In order that parents might be encouraged to send their children to the public schools, it was thought best not to receive pupils under 15 years of age.

The number in each class was limited to sixteen, so that each boy might receive proper attention. Of the first class only eight passed through the full year's course. At the end of the year, on June 29th, 1880, a public examination was held with the most gratifying success.

The second year opened on the 1st of September, 1880. Nine candidates were then admitted after examination, and three more later in the course; one pupil has been dismissed. The school now comprises nineteen pupils, seven in the advanced and eleven in the preparatory class. There is also one boy in attendance at the drawing lesson who is too young for the other classes.

Thus far the regular instruction has been given only for two hours each evening, Sunday excepted. At times when the pits are closed the pupils are requested to attend during the day from 9 to 12 A.M. and 2 to 5 P.M., the time being occupied in the drawing-room or in solving problems, or in review. If a sufficient number of boys from the regular classes are present, the regular studies are pursued. Attendance during the day is, however, voluntary.

The limited, and to some extent uncertain, time devoted to instruction is a disadvantage to the school, but it must be borne in mind that the school is as yet an experiment, and that the boys and their parents have to learn from experience that an education is worth the pecuniary sacrifice which would be involved in working half time and attending a day-school.

The interest evinced by the pupils thus far is very gratifying, as is shown in the following figures, expressing their attendance and progress during the first three months of the session:

For attendance—Grades, .	10	9½	9	8½	8	7½	6½	5
Number of pupils, . .	4	3	5	1	3	1	1	1
For progress—Grades, .	9½	9	8½	8	7			
Number of pupils, . .	1	4	6	5	3			

A grade of 10 signifies "perfect" and 5 "indifferent." The plan of instruction is, in general, as follows:

I. *The Preparatory Class.*—In this class English branches are taught—spelling, reading, writing, grammar, the elements of composition, arithmetic, and geography. An assistant teacher has charge of these branches. Algebra is studied as far as involution and evolution. In teaching geometry, particular stress is laid on the names, properties, and relations of geometrical figures in connection with geometrical construction in drawing. Both free-hand and mechanical drawing are taught with especial regard to developing artistic perception and the power of correct expression. Object lessons are also given to stimulate the reasoning faculties, which we often find but very imperfectly developed. In this preparatory class it is intended to admit boys under 15 years, that they may be well drilled in the elementary branches and better prepared for the next class.

II. *The Junior Class.*—In this class the English branches are continued, particular attention being paid to composition. The elements of bookkeeping are also taught, which serves, by the way, for an exercise in writing and arithmetic. Algebra is continued to equations of the second degree, with one or more unknown quantities, series, and exponential equations including logarithms.

The boys are also drilled in mental arithmetic and algebra to develop the power of quick perception and decision. The course in geometry is completed, including trigonometry, mensuration, and solid geometry. There is also provided an elementary course in analytical geometry, which is taught as algebraic projection in relation to geometrical projection and mathematical drawing. Geometry is divided into two parts—algebraic and practical geometry. In the first the subject is developed algebraically, with the aid of the trigonometrical properties of angles; in the second, the practical applications are seen in the solution of problems and in construction of figures both on the drawing board and in the field. A course in geometrical projection aims to give the pupil facility in drawing any figure in plan, elevation, or section which may be called for, both with instruments and free-hand.

In the course of mathematical physics, instruction is given in the elements of natural philosophy. To save time the mechanical portions, as for instance, the laws of motion, centre of gravity, the mechanical forces, etc., are treated mathematically, and the course becomes thus a combination of elementary mechanics and natural philosophy. Where feasible, experimental demonstrations are given.

Chemistry is taught so that the pupils may become acquainted with names, properties, and combining proportions of the most important elements, particularly with those which enter into the composition of the common minerals. Simple chemical tests for minerals are also taught. The instruction in mineralogy and lithology is confined to the more generally occurring minerals and rocks, and those in which the miner or manufacturer has the most immediate practical interest. In this junior class a thorough knowledge of elementary mathematics and drawing is considered the basis for all subsequent instruction.

III. *The Senior Class.*—The course of instruction laid out for this class will include the writing of a plain, intelligible report upon some practical subject, either directly from investigation or from memory. This concludes the instruction in English branches. In the drawing-room the work will include the elements of construction in wood, stone, and metal, making working drawings, and designing simple structures and machinery. Lectures will accompany this course.

The subject of mining will be treated systematically under the following heads:

I. Mining; including,

1. The useful minerals and metals; their occurrence, and the methods for their exploration.
2. The various means employed for the extraction of ores, etc.
3. The opening and laying out of mines.
4. The method of exploitation.
5. The maintenance of mines in good order.
6. Transportation.
7. Drainage.
8. Ventilation.
9. Mine surveying and mapping.
10. Accidents in mines, and their prevention.
11. Mining accounts, contracts, and estimates.
12. Hygiene of mines, with the remedies to be adopted in case of accident.

II. Preparation of the useful minerals for smelting or for market, which will include the machinery used in ore-dressing and in the mechanical preparation of coal.

During the senior year there will be practical exercises in the mine and in the field, which will involve the presentation of reports to the principal.

It is possible that there may be formed a fourth class, to be known as

IV. *The Expert Class.*—This class will enable pupils and graduates at their leisure to continue their studies with the instructors outside of the regular classes, and thus perfect themselves in certain branches already gone over, or to take up studies not provided for in the course.

It is required that all the pupils must have regular work in the mines or in the shops, and, as far as possible, arrangements are made to accommodate them.

The instruction is entirely free, the pupils providing only their books and materials. Annual public examinations take place and prizes are awarded to the best scholars.

The school-rooms are in Cross Creek Hall, a large building 106×51½ feet, having a basement room 12 feet high and an upper hall 42 feet high. In the basement are the office of the principal, 18×14 feet, two large class-rooms, 31×22 feet and 32×15 feet, and a drawing-room 28×18 feet. There are also a lecture-room, 49×30 feet, and a reading-room with a library the same size, all for school purposes. The reading-room is open every evening for the use of the employés. A separate building, 34×16 feet, contains the laboratory and lecture-room for chemistry and mineralogy. The school-rooms are open all day and until 9 o'clock in the evening. They are all lighted by gas and heated by steam. Collections of apparatus and minerals for purpose of instruction have been commenced, and it is the aim to illustrate the lectures as far as possible by facts from every-day practice. The instruction is given by the principal, assisted by Mr. D. D. Davidson, a graduate of Lafayette College, who teaches the English branches, bookkeeping, and elementary mathematics.

It is in the highest degree gratifying to record the praiseworthy conduct and punctual attendance of the boys; and the progress in their studies has been very fair, considering their previous ignorance.

The nationalities represented in the school are as follows:

Americans (9 of Irish descent),	12
Welsh,	3
Irish,	2
Swede,	1
French,	1

A noteworthy change is noticed in the pupils with regard to their appearance and dress, which are much improved by their attendance

at the school. The effect of the school is also shown in the expressions of regret heard from many young men that they had not entered the school at the start, and some of the foremen deplore the fact that there was not such a school when they were boys. The success of this school, let us hope, will induce others in charge of large works or mines to try the experiment.

It is to be recommended to start first, a preparatory class, say three evenings a week, and, in addition, to use the day hours when the mines or works are idle. When the boys are well prepared, a day-school, every afternoon for two years is desirable, the mornings being spent in practical work in the mines or shops. They should not, however, be employed in routine duties, such as picking slate, pushing cars, tending doors, etc. Such work tends to blunt the perceptions and stupefy the mind. If the suggestion above, of an expert class, is carried out for boys who have passed through the school, a very considerable technical training may be accomplished without taking an inordinate amount of time from working hours, or any considerable expenditure of money. The school must adapt itself to the works, which in turn must give aid and encouragement to the school. This co-operation is attained in some industrial sections of Europe, and I do not see why it cannot be introduced with us.

The keynote of success, let me say in conclusion, is not to endeavor to turn out young engineers, but to raise up intelligent foremen.

THE AMOUNT OF MANGANESE REQUIRED TO REMOVE THE OXYGEN FROM IRON AFTER IT HAS BEEN BLOWN IN A BESSEMER CONVERTER.

BY S. A. FORD, EDGAR THOMSON STEEL WORKS, PITTSBURGH, PA.

I WOULD like to call the attention of our Bessemer steel manufacturers to a few facts in regard to the action of the manganese in the spiegel with the oxide of iron in the blown iron.

The oxygen is united with the iron as a magnetic oxide, as Gautier asserts, and this oxide is reduced to a protoxide by one atom of the manganese uniting with one atom of the oxygen of the magnetic oxide of iron. This oxide of manganese and the protoxide of iron thus formed unite with the silica which has been formed by the oxidation of the silicon in the pig iron. Mr. Snelus and others

report finding in the blown iron from .29 per cent. to .35 per cent. of oxygen.

Many of our manufacturers, in making up their mixtures of spiegel, take the .35 per cent. of oxygen as the basis of calculation, and think that the whole of it unites with the manganese, and add spiegel accordingly, while in fact one-fourth of the .35 per cent. is all that is removed by the manganese.

I find that this amount is not at all constant; it varies according to the amount of manganese contained in the iron after the heat has been blown. I think the fact that we have been adding enough manganese to unite with the whole of the .35 per cent. of oxygen caused a superintendent of one of our largest Bessemer works to remark that he never made any calculation regarding the amount of manganese his steel would contain, for if he did he invariably went astray, so he preferred to add manganese by the rule of thumb.

Several months ago the Edgar Thomson Steel Works had trouble as to the amount of manganese in their special steels, analysis showing from .6 per cent. to .7 per cent. in them, while the superintendent of the converting department (who makes his calculations on the basis of .35 per cent. of oxygen) claimed that there could not be that amount of manganese in the steel, as he only put in 200 pounds of 69 per cent. ferromanganese in a charge of 17,900 pounds of iron. Now, by assuming that .35 per cent. of oxygen is removed by the manganese, this 200 pounds of ferromanganese would not give enough manganese, there being 56.38 pounds of oxygen in the iron, and only 138 pounds of manganese in the 200 pounds of 69 per cent. ferromanganese added. The 56.38 pounds of oxygen would require 193.88 pounds of manganese for its complete removal as oxide of manganese. If, therefore, the .35 per cent. of oxygen were the actual amount that united with the manganese, then the 200 pounds of ferromanganese was not enough, and some oxide of iron would be left in the steel and no manganese, or, at most, only a trace, instead of the .716 per cent. found by analysis.

In order to get at the bottom of this matter, I first analyzed the pig iron, then the iron that ran into the converter from the cupola. I found 1.945 per cent. of manganese in the former, and in the latter .987 per cent. The ferromanganese I found contained 68.9 per cent. of manganese, while in the iron, after it had been blown, there was .024 per cent. The heat of 17,900 pounds of metal had then 185 pounds of the ferromanganese added to it, and this steel had .608 per cent. of manganese. I found that .63 per cent of the iron was oxidized in blow-

ing, and this .63 per cent. of iron makes .87 per cent of the magnetic oxide, and this .87 per cent. contains .24 per cent. of oxygen. Now, only one-fourth of this amount, or .06 per cent., according to Gautier, unites with the manganese. By calculation it is found that instead of having 56.38 pounds of oxygen to be removed, there is but 9.66 pounds, and instead of being compelled to have 193.88 pounds of manganese, or 280 pounds of 69 per cent. ferromanganese, 33.23 pounds of manganese, or 48.23 pounds of the 68.9 per cent. ferromanganese, is all that is required to remove the oxygen. This steel, to which 185 pounds of the ferromanganese had been added, should have, therefore, .609 per cent. of manganese, for there was .024 per cent. of manganese in the blown iron, and the amount of ferromanganese which was added would put .585 per cent. in the steel, carrying the total to .609 per cent. By analysis, .608 per cent. was found—a proof of the correctness of our assumption. We now, therefore, instead of adding manganese haphazard, not knowing what we will get in the steel, can calculate to within .02 or .03 per cent. of the amount that it will contain.

METHOD FOR THE ESTIMATION OF MANGANESE IN SPIEGELS, IRONS, AND STEELS.

BY S. A. FORD, EDGAR THOMSON STEEL WORKS, PITTSBURGH, PA.

A SHORT and accurate method for the estimation of manganese in iron and steel is of great advantage to Bessemer works, and I think it may be of interest to some of the members of the Institute to give in detail the process in use in the laboratory of the Edgar Thomson steel works. The process is based on the reaction first described by Beilstein and Jawein.* The steel, spiegel, or iron is dissolved in strong nitric acid, sp. gr. 1.4. Evaporation to dryness is not necessary, unless the amount of silicon is large, as in the case of certain pig irons. Then, as a clogging of the filter in the subsequent filtration is apt to follow, dissolve first in a dish in hydrochloric acid, quickly evaporate to dryness, redissolve in the strong nitric acid, boil, and while boiling throw in crystals of chlorate of potash from time to time. Violent action ensues, yellow fumes are given off, and binoxide of manganese is precipitated, since it is insoluble in strong

* Berichte der deutschen chemischen Gesellschaft, vol. xii, page 1528.

nitric acid. As soon as all of the manganese has been oxidized the fumes will cease coming off with a slight explosion. After this has occurred, add a few more crystals of the chlorate of potash, boil for a minute or two, remove from the light and filter through asbestos. This I do by the aid of a filter pump, employing a small, funnel-shaped tube, such as is usually used for filtering the carbon from a solution of iron in the double chloride of ammonium and copper. This tube is inserted into a doubly perforated cork, which fits a wide-mouthed flask, and, by means of the other perforation, is made the attachment to the pump.

Having fitted the cork thus arranged into the flask, put into the tube a plug of asbestos through which the nitric acid solution of the iron is filtered. The manganese will all remain upon the filter; I have never found a trace of manganese in the filtrate. Rinse then the dish or beaker in which the iron was dissolved with strong nitric acid, pour it upon the filter and wash with strong nitric acid until the washings come through colorless. The funnel-shaped tube is removed from the flask; the filter, with its contents, pushed back into the dish or beaker in which the solution was made, hydrochloric acid added and boiled until the binoxide of manganese is dissolved as chloride. The asbestos is then filtered off. In doing this it is best to resort to the pump and the same tube, filtering into another flask; wash with hot water; nearly neutralize with ammonia; add a very small quantity of acetate of soda and boil; filter; wash slightly with hot water; redissolve the small quantity of oxide of iron in hydrochloric acid (as I always find it contains a small amount of manganese, no matter how thoroughly washed), and again nearly neutralize with ammonia and add a small crystal of the acetate of soda, boil and filter. Add this filtrate to the first filtrate, heat to nearly boiling, and add an excess of microcosmic salt. Then make slightly ammoniacal and boil, stirring until the precipitate assumes the well-known silky appearance of the phosphate of ammonia and manganese. Allow to settle and filter; wash with hot water, dry, ignite, and weigh as pyrophosphate of manganese.

This process works exceedingly well on blast-furnace slags, which should be dissolved in hydrochloric acid and evaporated to dryness. The nitric acid is then added and the process continued the same as for steel or iron. To free it from the lime, however, a more thorough washing with the strong nitric acid is required.

The great advantage of this method is its brevity and simplicity, a person with some little practice being able to complete three or four

determinations in two hours. There is no large precipitate to wash, as in Mr. Pattinson's process, and the necessity of several standardized solutions is avoided. It gives results which vary but slightly the one from the other, the difference never being greater than one or two hundredths of one per cent., and the results accord very closely with those obtained by the long, tedious acetic process. In the iron solution filtered from the oxide of manganese I have never found a trace of manganese, and in the solution filtered from the phosphate, neither bromine nor sulphide of ammonium gives the slightest precipitate of manganese. Evaporation to dryness in the case of steels or spiegel is not absolutely necessary, but they may be at once dissolved in the strong nitric acid, and chlorate of potash added. I never found a trace of silica in the phosphate of manganese obtained from a steel or spiegel treated in this way.

AURIFEROUS SLATE DEPOSITS OF THE SOUTHERN MINING REGION.

BY P. H. MELL, JR., M.E., PH.D., PROFESSOR OF NATURAL HISTORY AND GEOLOGY, STATE AGRICULTURAL AND MECHANICAL COLLEGE, AUBURN, ALA.

CAN the auriferous slate deposits of the Southern mining region ever be successfully worked? is a question that has been often asked me by persons seeking investments in Southern mines. As the subject is one that has given me much thought during the past few years, I have decided to present my conclusions to the members of the Institute for their consideration. Those who have had the opportunity of exploring the region mentioned above, will readily recall to mind numerous localities, to which their attention was directed by would-be miners, as "rich and desirable properties," in which there were but few quartz *seams* running in every direction through fine-grained talcose slate. Most of the gold in such formations was always found disseminated through the slate, and but a small percentage contained in the quartz. Such are the deposits I propose to discuss in this paper.

Of course there are many excellent quartz mines in the South that are paying the owners good profits, and many more to my knowledge, that are not being worked for obvious reasons. But it is out of the question to suppose that these slate deposits can be practically

worked by the same methods adopted for extracting the ore from well-defined and prominent quartz veins. It is true that in many instances these slate formations are quite rich in gold, but this is not uniformly the case, and, as there is no chance of sorting the ore, handling so much crude and dead stuff in the ordinary way of mining and milling would be ruinous.

It has been my privilege to examine quite a large number of these formations in the South, and, as a general thing, they were found so thoroughly decomposed, as to render it not at all difficult to spade the slate, and pulverize the whole mass between the fingers. These formations are sometimes several hundred feet in width, extending to unknown depth, and varying in length from a few hundred feet to several miles. In fact, in every respect, except as to composition and location, they bear a striking resemblance to the ordinary gravel deposit.

Now, why cannot these slate formations be worked by water, somewhat in the same way as ore is concentrated in gravel beds? This plan has, in part, been adopted by N. H. Hand & Co., in working a property located near the Pigeon Roost region, Lumpkin County, Ga. The idea seems to have suggested itself to these enterprising men from the surrounding circumstances. It is well known that for a number of years this company have been supplying their mines with water from a well-constructed ditch over 26 miles in length, and by means of this ready agent they have successfully worked the slate vein mentioned above. Before N. H. Hand & Co. took possession, the property was very thoroughly tested by the old plan of driving shafts and extracting the ore by means of picks and shovels. Very expensive and elaborate machinery was employed, but without success, and the property was eventually abandoned with considerable loss to the company. When the present owners, therefore, took possession, the past history of the mine contained but little to encourage them in the prosecution of the enterprise. There was no regularly defined vein of quartz, but simply a large mass of fine-grained talcose slate, throughout the length and breadth of which good pannings of gold were obtained. A twenty-five stamp battery, run by water, was erected one-half mile from the mine, at the lowest point accessible. On a high hill in the neighborhood of the mine a large reservoir was supplied with water from the ditch mentioned above, and by means of a "Little Giant," in connection with this reservoir, playing under a pressure of 150 feet head, the

vein of decomposed slate and quartz was driven through riffle-boxes towards the mill.

The inclination of these boxes was sufficient to carry everything in the nature of ore into the mill-house, and the force of the water being broken there by mechanical means, only the finely pulverized slate and floating mud were permitted to pass away and settle wherever opportunities were presented in the various gulches. It was of course necessary at times to break up by means of hammers, or otherwise, any large bowlders that were washed down from the vein before permitting them to enter the riffle-boxes. But these were of such rare occurrence that two to four men were all that were necessary to supply the mill with ore. The net profits yielded by this mine per week in 1879, under the above treatment, were $800.

The unused water power of the Southern gold belt is immense, and if companies could be formed to build the proper water ditches to reach these present worthless properties, there would be a wonderful revolution and revival in the mining interests.

From the geological reports of Georgia I find that there are 180 prominent streams in the gold belt of that State, that furnish in the aggregate 26,000 cubic feet of water per second, the capacity of each stream varying from 2 cubic feet upward as high as 3000 cubic feet per second. This amount of water would give, with an assumed head of 100 feet, 285,640 theoretical horse-power, or 190,426 available horse-power. Again, 26,000 cubic feet per second would be equivalent to 1,560,000 cubic feet per minute, and this volume of water confined in a ditch would supply about 700,000 miner's inches.

North Carolina and Alabama are not behind Georgia in the supply of water, and the most of this vast power is running unused to the sea. Professor Kerr, State Geologist of North Carolina, has given in his report a full and interesting description of the valuable streams of his State, and in some instances gives the estimated water power. It would be interesting to read this report in connection with this article.

Custom mills should be built at intervals throughout the region, and this water utilized for not only washing down and concentrating the ore, but also transporting it, if possible, to the mill ready for crushing and amalgamating. Upon actual experiment in Georgia, it has been found that by such treatment ore can be profitably handled that yields but 75 cents per ton. Last year the manager of the Findley informed me that where the ore could be reached by the

water, he had succeeded in mining and crushing at a cost of but 28 cents per ton. This was the case, however, where the water was made not only the mining but the transporting agent as well.

The climate is delightful the year round, and seldom are the streams so locked up with ice as to suspend all mining operations. Railroads are running within a few miles of the farthest point of the mining region. Provisions are cheap, and in great abundance. Labor is to be had in sufficient amount, ranging in value from 50 cents per day for ordinary hands to $1.50 per day for mechanics. The forests are also in their original beauty and abundance, and there is, of course, no lack of wood for building and fuel purposes. So, in summing up, it would not be far from right to assert that, with all these advantages, the same class of ore that is now cast aside as worthless on the Rocky Mountain slopes, could be profitably worked in North Carolina, Georgia, and Alabama.

THE CONSTRUCTION OF GEOLOGICAL CROSS-SECTIONS.

BY H. MARTYN CHANCE, M.D., ASSISTANT GEOLOGIST, PENNSYLVANIA SURVEY.

I HAVE been induced to present this paper to the Institute because I have been unable to find any publication containing a discussion of this subject. In some of our technical schools and colleges the student is required to construct or copy (generally the latter) a number of profile sections as part of his routine work; but little attention is given to the methods of projecting observed dips and exposures upon the section line, and still less to the method of constructing the under (or above) ground curves. As a result of this lack of instruction every engineer or geologist is compelled to invent for himself a system, or copy the style of others.

Geological profile sections have frequently been used to determine underground structure from data obtained at the surface, but the experience of engineers in the anthracite coal-fields has shown that they are to be relied upon only in exceptional instances.

The possibility of indicating underground curvatures from dip-angles observed at the surface has been found to be limited to a mere approximation of the larger flexures. As a means of predicting the depth and shape of minor rolls, they have been found most unsatisfactory. In the anthracite coal-fields the hypothecated

structure in undeveloped ground is usually introduced upon the working profiles in pencil-lines only, and as development progresses frequent changes are necessitated by the eccentricities of individual seams.

I wish to invite attention to the methods commonly used in the construction of cross-sections, and to indicate some of the reasons why these must always fail to give trustworthy results.

We may consider these points under three heads:

1. The location of the section line.
2. The projection of dips and exposures.
3. The construction of underground curves.

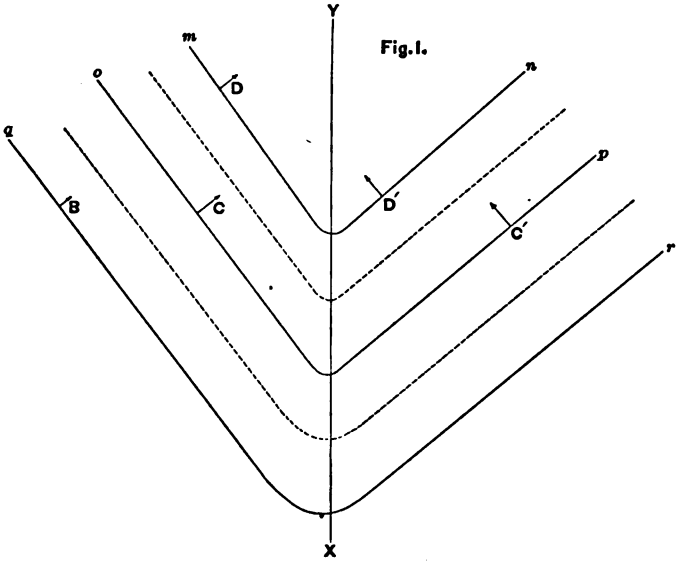


Fig. I.

Having given a series of exposures and dip-angles located geographically upon a map, the best position for a section is generally conceded to be along a line drawn midway between these exposures and at right angles to the line of strike, *i. e.*, parallel to the direction of the dip.

If the section line cross is an anticlinal or synclinal axis decidedly inclined to the horizon,—that is, when the opposing dips are not parallel and the lines of strike on opposite sides of the axis converge, —the section may often be best located along a broken line, the lengths of which are drawn at right angles to the local strike; or it may be constructed on a line drawn at right angles to the axis, when

this bisects the flexure; or on a line drawn at right angles to a line bisecting the angle formed by the converging strike lines.

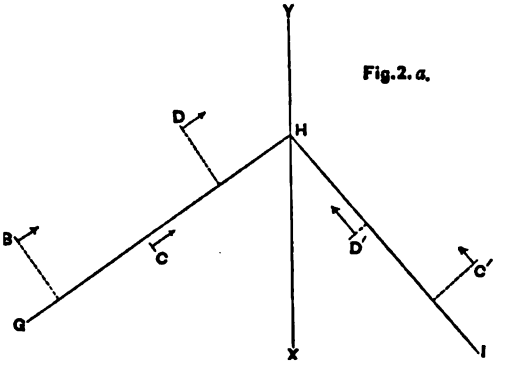


Fig. 2. a.

Thus in Fig. 1, three coal beds, B, C, D, are exposed at the points, B, C, D, D′ and C′, dipping as indicated by the arrows; the line

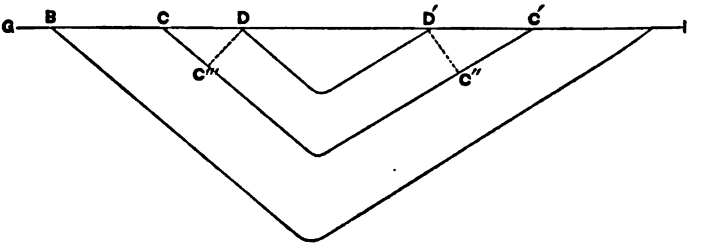


Fig. 2. b.

XY is the axis of the flexure, rapidly declining towards Y. The lines *mn*, *op*, *qr*, are water-level contours drawn through the different

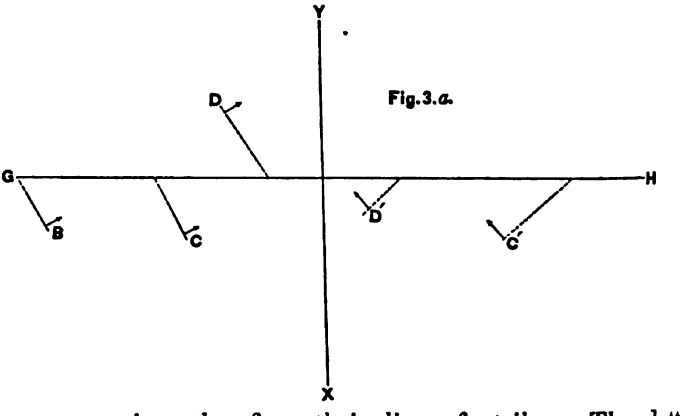


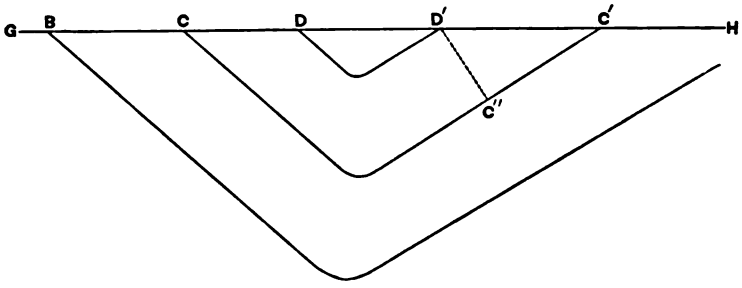
Fig. 3. a.

seams, representing, therefore, their line of strike. The dotted lines are introduced to show the method of locating hypothecated horizons.

The best method of constructing a section through these exposures is illustrated by Fig. 2, *a* and *b*, in which the section line GHI is a broken line, the segments of which, drawn parallel to the opposing dip-angles, intersect on XY.

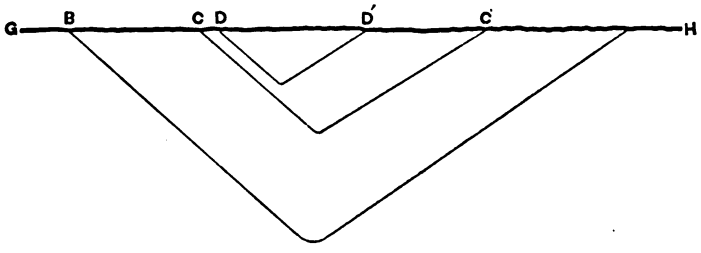
The resulting section shows the absolute thickness of the strata between B and C, and between C and D, and the agreement between the thickness DC''' with that determined at D'C'' furnishes a good check on the accuracy of the construction.

Fig. 3. *b*.



Two very objectionable methods are shown by Fig. 3, *a*, *b*, and *c*. The section line GH is drawn at right angles to the axis XY, and midway between the located exposures. The section, Fig. 3, *b*, is obtained by projecting the dip-angles upon the section line, *in prolongation of the line of strike.* This is the only proper way of projecting

Fig. 3. *c*.



exposures, and will always give a section mathematically correct for the adopted alignment, but the thickness of measures as represented by the section is much greater than the true thickness. This can be seen by comparing D'C'' in Fig. 2, *b*, with the same line in the section, Fig. 3, *b*. When this method is adopted a prominent "N. B." should always direct attention to this exaggeration.

The section, Fig 3, c, shows the absurd construction that results if the dip-angles are projected at right angles to the section line.

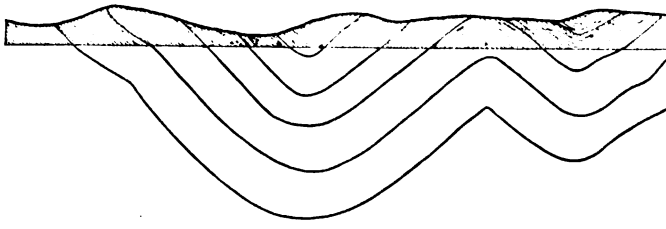
Difficulties in the identification of coal seams on opposite
a basin may frequently arise from distortions of this kind.

In the construction of underground curves, two method
general use:

1. By equal thickness.
2. By equal (parallel) dips.

The calculated thickness of each stratum is rigidly p
throughout in the first method, by making the curvature

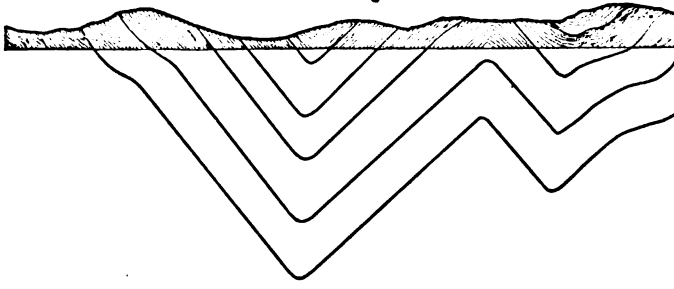
Fig. 4.



seam concentric to those above it. These curves are usua
pound curves composed of circular arcs.

When the second method is employed no attempt is usual
to preserve uniformity of thickness along the axes of antic
synclinal flexures, the opposing dips are prolonged until th

Fig. 5.



sect, and the curvature sketched in to suit the fancy of the d
man; but a combination of this and the preceding method
times employed.

The difference between these two methods is illustrated
4 and 5, in which the surface observations are identical,
underground (hypothecated) curves vary widely. In Fig.
stratum preserves a uniform thickness throughout, but i

the prolongation of the opposing dips produces an augmented thickness along the synclinal and anticlinal axes.

As it is evident that the first method will show the minimum depth of any coal in the basin, and the second the probable maximum depth,—in all but exceptional instances,—a combination of these two methods is apparently preferable, as more nearly approximating the probable underground curvatures. Such a combination has been employed by some members of the Geological Survey in the construction of many of the sections in Pennsylvania.

But there is a serious objection to any system, involving in whole, or in part, the method of equal thicknesses, viz., *the gradual obliteration of the surface flexures in the underlying rocks.*

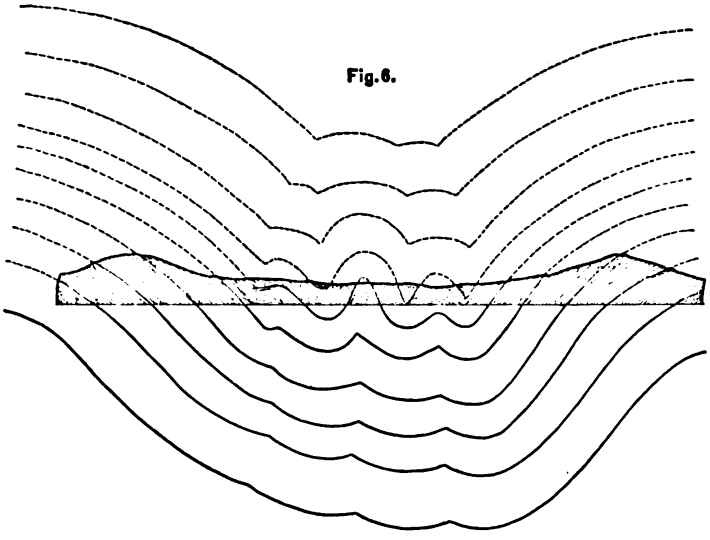


Fig. 6.

This is illustrated by Fig. 6, which is constructed partly on this system. It will be observed that the steepest dips are *along the line of observed exposures;* above and beneath this line the axes rapidly fade away, and can hardly be seen in the basal stratum. The same result obtains in the (restored) formations lying above the present surface.

Sections constructed on this principle (Figs. 4 and 6) will, therefore, always show the maximum curvatures along the line of observed dips. It is hardly necessary to say that any method uniformly giving these results must be essentially false. The apparent regularity of profiles so constructed lends false pretensions of accuracy to the section.

Under *one sequence of conditions only* does this method give results approximating the true underground structure. Having reference to Fig. 6, let us suppose the lower strata to consist of hard, massive sandstones, or conglomerates, and the upper rocks of soft slates or shales. If a lateral compressing (flexing) force acts upon this series, the lower massive formation will yield in curves of large radius, while the overlying softer strata compressed in the trough thus formed will be thrown into a series of crimples resulting in flexures similar to those shown in the section. If, on the contrary, the observed dips in the upper rocks are in hard strata underlaid by softer rocks, these latter would suffer the greatest contortion, whereas the construction shows them nearly flat.

I have lately made a series of experiments on rock contortion, by artificially compressing layers of clay, paper, india-rubber, wax, etc., and have attempted to deduce laws governing the relationships of the resulting curves, which might be practically applied to geological sectioning; but the factors involved are so numerous and vary between such wide limits that it seems an almost hopeless task. I have, however, arrived at some general conclusions that may be of service.

1. The subordinate flexures or sub-basins in a synclinal of soft rocks underlaid by a hard resisting formation, decrease in sharpness towards this basal rock.

2. If a series of soft measures underlies this hard formation, it may be contorted by a series of flexures bearing no relation to the upper series.

3. Where large masses of approximately uniform hardness are contorted by compression, the resulting curves bear close complementary relations to each other. (See Fig. 5.)

The first of the above propositions has already been referred to on a preceding page. When these conditions obtain, as in the anthracite coal basins, the coal-measure rocks are crimpled and distorted, while their hard basal plate of conglomerate has been arched into curves of large radius, with flat dips, as proved by diamond drill-holes. When these conditions obtain, the method of equal thicknesses, or a modification of that method (Figs. 4 and 6), will give curves more nearly approximating the underground structure than any other method.

On the Lehigh River we find a striking exemplification of the second proposition. At Slatington the Lower Silurian (roofing) slates, No. III, are twisted and contorted by a complex series of over-

turned flexures. Above these come the hard sandstones and conglomerates No. IV, forming the mountain, dipping down in gentle curves of larger radius beneath the softer Upper Silurian strata of Hazardville and Bowmansville. These latter are twisted, faulted, and overturned, but these flexures can have no possible relation to those in the roofing slates, lying five thousand feet beneath, and separated from them by the hard rocks of No. IV, which reflect the minor flexures of neither the former nor the latter. Under conditions similar to these it is of course utterly impossible to indicate the curves of the lower formation from any data obtained from the upper rocks.

The conditions of the third proposition are strikingly shown by cross-sections of the coal measures in some parts of France, in which the various coal seams are bent in a series of parallel zigzag lines. Here the second method, *i. e.*, by equal dips, is peculiarly applicable.

When the observed dips are in a hard, massive formation underlaid by softer rocks, the underground curves are always indeterminable.

Too much reliance is often placed upon geological cross-sections as a means of determining underground structure. In this their utility is limited, but as a means of estimating rock thickness, as a help to intelligent prospecting, and as a pictorial means of representing demonstrated and hypothecated structure, their value is great.

THE GOLD-BEARING MISPICKEL VEINS OF MARMORA, ONTARIO, CANADA.

BY R. P. ROTHWELL, M.E., NEW YORK CITY.

ABOUT thirty miles north of the city of Belleville (which is situated on a branch of Lake Ontario), and in the township of Marmora, Ontario, there is found a belt of gold-bearing quartz veins, which present geological, mineralogical, and economic features of great interest to the profession. The district in which these veins are found is characterized as a rolling country, with low rounded hills of syenitic granite, overlain on the flanks of the hills by Silurian limestones, which lie in nearly horizontal beds, and in some places are so fine in texture as to afford lithographic stone of a fair quality.

The gold-bearing veins run north and south through this belt of syenitic granite, and are quartz-filled true fissures, with micaceous or talcoid slates forming the walls of and horses in the veins. This

talcose, slaty rock is evidently the product of the chemical decomposition of the syenite along the fissures, the quartz being segregated from the country rock into the veins, and the hornblende of the syenite furnishing the magnesia of the talcoid slates. The veins, besides quartz, contain also, as gangue, crystallized calc-spar, and occasionally crystallized black mica. The ore scattered through this gangue, in heavy bands in some places and in detached, well-formed crystals at other points, is an arsenical sulphuret of iron (mispickel), having a composition of about 55 per cent. of iron and 25 per cent. of arsenic, and perhaps 20 per cent. of sulphur. This mispickel contains the greater part of the gold for which the mines are worked, but free gold is also found scattered through the quartz in small leaves and grains, and it is also found, showing freely at times, in the mispickel itself.

The tests which have been made of these veins and their ores have so thoroughly established the facts of the continuity of the veins, both in length and depth and the economic value of the ores, that the interest which would naturally be taken in so promising a prospect as this was, even before development, has now deepened into the substantial form of an interest in a great industrial enterprise.

Gold was first discovered in this district in 1865 as free gold in quartz and mispickel, and sporadic attempts have since been made at two or three points to treat the ores, chiefly by raw amalgamation. As might have been anticipated from the nature of the ore, but a very small proportion of the gold was saved in this way, while the expense of treatment in the small and primitive mills adopted was great and the loss of quicksilver heavy. There was neither experience nor technical knowledge available at the time, and no sufficient capital to put up suitable works or to develop the mines; hence they have lain idle all these years without a single serious effort to work them on an economical basis. Nevertheless, many tests of the ores were made, some on quite an extensive scale, in reduction works in the United States and England, and the results were invariably highly satisfactory.

By far the most extensive and the only systematic tests of these veins and their ores have been made upon the properties shown in the accompanying maps, and which form a portion of the properties combined under the ownership of the Canada Consolidated Gold Mining Company.

From these tests some four or five parallel veins have been proved to exist in a belt of 500 or 600 feet in width, running through the

property of this company for a length of over three-quarters of a mile, while the main vein has been opened on adjoining properties, making a total proved length of this great fissure of about three miles on the vein, a fact which, next to actual sinking, may be considered the best proof of the continuance in depth of the veins. Three of these veins have been proved on this property by costean pits and shafts sunk at short intervals along their outcrops, to depths varying from 15 to 150 feet. In this manner, the east or main vein has been thoroughly explored over a length of about 800 feet by shafts of from 40 to 150 feet in depth; these have, in every case, been in pay-ore all the way; their lowest points are now in as good ore as has been found on the property; and they have shown this vein to have a thickness exceeding 20 feet in many places, and averaging probably 8 or 10 feet, while the middle and west veins, though smaller, have still apparently a thickness of three feet and upward. As each foot of thickness for a length of 700 feet and a depth of 150 feet will yield about 10,000 tons of ore, the estimates which count as technically in sight, in this small part of this vein alone, from 60,000 to 75,000 tons of ore, must be considered very moderate. These estimates and some much higher have been made by a number of experts of large experience.

Perhaps the question of greatest interest is the average gold contents of the ore; and as this has been determined in a very thorough manner under my own supervision, I shall enter somewhat into the detail of the work, as showing what is considered essential in determining with safety the average value of a gold ore and of a mine.

Some three or four thousand tons of ore have been mined upon this property, and of this about a half has been milled or treated in a variety of ways, and the remainder is now on the dumps. The first tests of these ores were made from samples selected by various experts who have from time to time examined the property. Some of the results were as follows:

Twenty assays, made at the laboratory of the Geological Survey of Canada, of samples from the Marmora mines, gave an average of 1.6367 ounces of gold, equal to $33.81 per ton of 2000 pounds. Twelve of these samples were from the Gatling mines, and gave an average of 1.9107 ounces of gold, or $39.47 per ton.

Professor E. J. Chapman, of the University College, Toronto, says: "I have made assays of its ores from time to time, and I have never failed to obtain from any sample (mispickel), as a minimum

value, at least $50 per ton." "The following results were obtained from samples collected very carefully, with a view to obtain the average amount of precious metal held by the undressed ore: No. 1, or East Vein—Gold, $73.50; silver, ¼ ounce. No. 3, or Middle Vein—Gold, $69.86; silver, ¼ ounce. O'Neil Shaft, middle vein—Gold, $60.26; silver, ¼ ounce. On a former occasion, I obtained from a small sample of the Gatling ore $112, and from pure mispickel $156 per ton."

Mr. James Douglas, Jr., Mining Engineer, says: "A sample taken as fairly as possible from the ore-piles on the Gatling Company's property, the five-acre lot, and the Hawkeye lot, gives me in gold 1 oz. 5 dwts., value, 25.84 per ton of 2000 pounds."

Professor W. T. Rickard, of London, says: "I took samples from the various shafts and openings on each claim, and ground them together. . . . I picked out a large quantity of pure mispickel, crushed and sampled, and assayed the same. . . . I deducted the estimated amount of quartz, associated with the mispickel, and then allowed 50 per cent. for depreciation in the quality of the mispickel. The following results were obtained by careful assay:

"*Hawkeye ore* from three shafts, mixed mispickel—Gold, $753.48; silver, $15.71. Total, $769.19.

"*Gatling five-acre lot.*—From one shaft quartz—Gold, $200.93; silver, $3.14. Total, $204.07 per ton.

"*Gatling Company.*—From three shafts, mixed mispickel—Gold, $351.63; silver, $21.91. Total, $373.54.

"*Gatling Company.*—O'Neil Shaft, third vein—Gold, $376.64; silver, $7.85. Total, $384.49.

"*Tuttle Property.*—Surface quartz—Gold, $125.48; silver, $4.70. Total, $130.18.

"*Average*—First-class quartz and pure mispickel, . .	$372 29
Deduct ⅕ ton for gangue in bulk, leaving . . .	74 46
" ½ ton for inferior mispickel, leaving . . .	87 23
" for loss in reduction $7 23, leaving . . .	80 00

Or net yield of ore in treatment $80 per ton."

F. W. Dahne, Esq., who dressed a lot of this ore sent to Swansea, says: "The ore I treated contained, before dressing, 2½ ounces of gold to the ton (2240 pounds)."

Captain Benjamin Plummer, who examined these mines for Messrs. John Taylor & Sons, of London, carefully sampled the ores from the different openings, and had his samples assayed by Professor Chapman, of University College, Toronto, who obtained the following as

the average of a number of assays, gold counted at $20.66 per ounce troy:

Sample No. 19, Gold $38.65 per ton of 2000 pounds.
" No. E, " 24 87 " "
" No. F, " 86.60 " "
" No. G, " 24.74 " "
Average, $31.21.

The amount of silver in these samples never exceeded ½ ounce per ton.

TESTS ON A LARGER SCALE.

Two barrels of average ore treated at Balbach's works, in Newark, N. J., yielded:

From East Vein—Gold, $23.76; silver, $4.07. Total, $27.83 per ton of 2000 pounds.

From O'Neil Shaft.—Gold, $25.62; silver, $4.39. Total, $30.01 per ton.

Four barrels of ore sent to Messrs. Richardson & Co., Swansea, yielded as follows (assays being reduced to dollars per ton of 2000 pounds):

Tuttle Shaft.—Gold, $93; silver, $7 per ton (2000 pounds).

Gatling Company's Deep Shaft.—Gold, $37.21; silver, $20 per ton (2000 pounds).

Gatling Company's A Shaft.—Gold, $23.15; silver, $18 per ton (2000 pounds).

Gatling Company's O'Neil Shaft.—Gold, $23.15; silver, $100 per ton (2000 pounds).

The report for a large lot of ore from the O'Neil shaft, subsequently sent to the same Swansea parties, was as follows:

For 19.8 tons: Gold, $23.15; silver, $0.50 per ton of 2000 pounds.

For 9.9 tons: Gold, $27.90; silver, $0.75 per ton of 2000 pounds.

For 4.4. tons: Gold, $55.81; silver, $0.50 per ton of 2000 pounds.

Analyses of pure mispickel, made by Thomas Thomas and J. Hernaman James, Assayers in Swansea, to Messrs. Richardson & Co., were as follows (the gold being reduced to dollars in a ton of 2000 pounds at $20.67 per ounce):

	SMALL CRYSTALLIZATION.	LARGE CRYSTALLIZATION.
Peroxide of iron	54.00	56.00
Silica	0.51	0.03
Sulphur	19.03	18.13
Arsenic	25.70	23.00
Nickel	trace.	trace.
Silver (per ton of 2000 pounds).	trace.	$6.50
Gold (per ton of 2000 pounds)...	$306.95	$2920.67

Mr. E. W. Harmon, in 1876, tested the ores from these properties in the interest of Boston parties, who had a patent process for treating sulphuret ores. The following are the results obtained by Mr. Harmon from average samples selected by himself:

	Per ton of 2000 pounds.
No. 1. East Vein Gatling Company, gold,	$123 84
" 2. " " "	37 84
" 3. " " "	37 84
" 4. " " "	75 68
" 5. Middle Vein " "	48 16
" 6. " " "	116 96
" 7. West Vein " "	41 28
" 8. " " "	120 40
" 9. Sample from all of foregoing,	61 92
" 10. Gatling South,	41 28
" 11. " five acres,	550 40
" 12. " "	595 12
" 13. " "	37 84
" 14. Williams mine, tailings,	34 40
" 15. Gatling Company—Shaft, free gold,	440 32
" 16. Gatling roasted steely ore, amalgamated,	48 16
" 17. Gatling rich pyrites, raw treatment,	1265 92
" 18. 1 pound average material from first test by a stirring (amalgamating) process,	52 46

18.7 tons of ore from the several shafts of the Gatling Company's mines were then treated by the same parties, the process being roasting and amalgamating; the roasting was very imperfect, being effected in a revolving cylinder only 3 feet diameter and 12 feet long, heated from the outside, and with a strong draught of air forced through it by a blower. The consequence was, that the flue-dust contained much gold, and the roasted ore carried 6 per cent. of sulphur.

The following were the assays of lots of from two to three tons each:

	Ore.	Tailings.
No. 1,	$30 90	$30 30
" 2,	41 20	6 67
" 3,	65 23	6 87
" 4,	41 20	6 87
" 5,	51 50	8 58
" 6,	44 71	12 04

Average gold in 18.7 tons was $35.46 per ton, counting gold at $20 per ounce.

Gold actually saved was $25.32 per ton, or 71 per cent. of assay value, while there was still in the bottoms in flue-dust returnable for retreatment, obtainable gold that would have made the yield $27.31 per ton, or 77 per cent.; and the tailings were extremely

rich, and could easily have yielded on shaking tables or belts gold enough to have made the actual yield $30 or $31 per ton.

Captain Thomas Couch, Mine Superintendent, in his examination of these mines, in February, 1880, carefully sampled the several mines, taking one and two ton samples of the ore just as it came from each of the shafts and levels, without sorting.

The results were as follows:

	Gold.	Silver.
Tuttle shaft, 2 tons,	$26.46 per ton.	1 28 ounces.
Deep shaft levels, 2 tons,	16 83 "	.79 "
Middle vein, 2 tons,	32.65 "	1.58 "
N. Hawkeye shaft,	7.85 "	.38 "
S. Hawkeye shaft	7.44 "	.36 "
Concentrates (Tuttle shaft),	137 48 "	6.65 "
" (Levels deep shaft),	65.00 "	3.14 "
" (Middle vein),	107.48 "	5.20 "
"	129.19 "	6.25 "

Assayed by W. E. Gifford, 54 Pine Street, New York.

Mr. R. H. Stretch, Mining Engineer, sampled the mines by taking one-ton lots of the ore just as it came from the several shafts and levels, without sorting, and the result of his assays was as follows:

Deep shaft, bottom,	$21.50 per ton.
N. level,	9.00 "
S. level,	7.50 "
A shaft (8 samplings),	17·92 "
Tuttle shaft,	19.00 "
Average after parting; gold,	13.06 "

By far the most exhaustive tests of these ores were made under my own direction. Having secured a working bond upon these properties, I carried on mining and milling operations with a force of eighty or ninety men during nearly four months. During this time, seven shafts were worked upon and attained depths of from forty to one hundred and ten feet; and two levels of forty feet each in length were driven. Three of these shafts, namely, the Tuttle, the A shaft, the deep shaft, and two levels were those upon which the most work was performed, and it is to the ore from these that the following remarks are confined. These openings proved a length along the main vein of about seven hundred feet, as may be seen by reference to the accompanying maps.

The ore extracted, *without any sorting whatever*, was taken to the mill; it was then weighed and crushed for the greater part in five-ton lots, every twentieth shovelful as it came from the Blake crusher being laid aside for a sample. The samples of five-ton lots were crushed fine, quartered down as usual, and assayed; thus, one

hundred and eight lots, nearly all representing five tons of ore, were assayed separately, while fifty-one tons from the Tuttle shaft were sampled in the same careful manner in one lot by Mr. Thomas Macfarlane, of the Wyandotte Silver Smelting Company. The assays of these several samples are given in the following table. It will be noted that the richer five-ton lots were obtained by selecting the heavier sulphurets from the remainder of the ore in the ore-house so as to demonstrate the effect of rough hand-sorting; the low assays were therefore of second-class ore; the whole number of assays gives, however, the average yield of the ore just as it comes from the mine without sorting. The higher assay numbers (last assays made) were, in general, from ore mined nearest the surface, and which accordingly was found at the centre of the dump. Nearly one-half the dump was milled, and the last milled came from the centre of the dump.

NOTE.—The proportions of gold and silver in the assay buttons were obtained by parting 89 buttons in one operation. It was found the average was 68 per cent. gold, 32 silver. The following table gives only the gold, or 68 per cent. of the weight of the button:

Record of Assays of Canada Consolidated Gold Mining Company's Ores, mostly from the Gatling Mine—108 *samples, mostly* 5 *tons each, representing a total of* 515 *tons of* 2000 *pounds.*

1	$33 04	28	$6 33	55	$9 84	82	$10 90
2	14 06	29	8 08	56	42 18	83	11 07
3	9 84	30	25 31	57	28 12	84	9 49
4	18 98	31	7 03	58	27 06	85	7 38
5	43 94	32	33 74	59	14 76	86	4 57
6	15 11	33	7 38	60	39 37	87	5 98
7	11 60	34	7 38	61	11 25	88	32 34
8	10 55	35	6 50	62	9 84	89	7 03
9	14 76	36	12 65	63	23 20	90	7 73
10	8 44	37	16 17	64	16 17	91	5 62
11	11 60	38	9 84	65	9 49	92	33 04
12	8 79	39	18 28	66	8 44	93	32 34
13	9 84	40	21 79	67	12 65	94	15 47
14	9 14	41	14 76	68	10 72	95	6 33
15	7 73	42	7 03	69	10 90	96	9 49
16	11 25	43	10 55	70	6 33	97	17 58
17	16 17	44	7 73	71	5 27	98	17 58
18	14 06	45	4 92	72	8 44	99	9 14
19	7 38	46	9 14	73	9 84	100	5 45
20	11 25	47	53 43	74	5 62	101	12 83
21	9 49	48	5 62	75	7 38	102	13 36
22	7 03	49	5 62	76	12 48	103	4 92
23	9 14	50	5 62	77	11 07	104	15 11
24	8 79	51	17 58	78	5 98	105	5 62
25	11 25	52	13 71	79	7 03	106	28 12
26	8 44	53	18 98	80	10 90	107	11 95
27	18 28	54	8 44	81	8 26	108	7 03

Average 108 samples, 515 tons Gatling ore, assayed by A. Thies, $13.37 gold per ton.
Check assays, by Prof. Richards, of Boston, and Gifford, of New York, $14.75.
Average value Gatling ore, East vein, $14.06 per ton.
Average samples, aggregating 63 tons Tuttle shaft, East vein, $24.88.
Average samples, aggregating 12 tons, Middle vein, $30.82.

Allowing the proper proportion of ore-reserve to each of these shafts, the average assay value of the ore in reserves I find to be $18.65 in gold per ton.

From these most exhaustive tests, the average gold contents of the ore were determined with great accuracy.

Perhaps the most interesting and certainly one of the most important and valuable facts developed was the very remarkable uniformity of the gold yield of the ore. In only three instances—even of second-class ore after the richer ore had been roughly picked out—was less than five dollars per ton in gold found, and the highest assay of a five-ton lot was $53.43 per ton. Samples of a few hundred pounds have been found to run as high as $150 per ton, and hand samples very much higher; but these were not considered as safe guides in valuing a mine, and were therefore rejected as exceptional.

THE TREATMENT OF THE GOLD-BEARING MISPICKEL.

When I first commenced testing these mines, about fifteen months ago, I was met by a vast array of *dicta* concerning the difficulties to be encountered in roasting, in amalgamating, or otherwise getting the gold out of arsenical sulphurets of iron. It is fair to add, however, that these difficulties were always reported by *persons who had not themselves worked such ores*, but had "always understood" they existed. No satisfactory record of tests actually made with such ores being on record, so far as I knew, I determined to make history myself; and though in some particulars we have still very much to learn, the facts which were established may be of use to the profession, and I gladly communicate them.

As there could be no possible question about the facility of concentrating mispickel, with a specific gravity of about 6 or 6½, from quartz and calc-spar, with a specific gravity of about 2½, we did not consider it necessary to build concentrating works to test that point; and as there was no concentrator except a centre-discharge buddle taking all the ore as it came from the battery (with forty-mesh screens) without sizing, it was no matter of surprise that at times one-half of the gold was lost in this operation. That, however, was not so much a consideration with us as to determine points upon which knowledge was not obtainable.

The ores were sampled in the manner mentioned above before going through the battery. After concentration, the concentrates from some two or three hundred tons were roasted in a muffle furnace, those from nearly six hundred tons in a reverberatory, and those from several hundred tons in a revolving cylinder. The results in all

cases showed that these arsenical sulphurets roast with the greatest facility, and in much less time than simple pyrites, owing probably to the fact that the arsenic is volatilized at a much lower heat than the sulphur, and in escaping it leaves the ore in a measure porous, and therefore in suitable condition for oxidizing the sulphur. The consumption of fuel was far greater in the reverberatory and muffle furnaces than in the revolving cylinder, where indeed one cord a day would roast ten tons of ore.

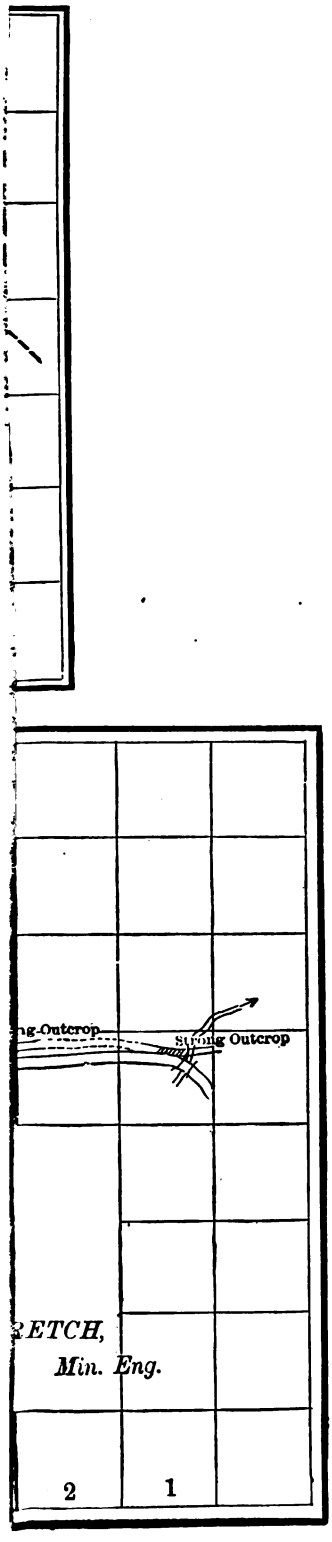
There was no comparison, either, in the cost of labor in these different systems (in the revolving cylinder it was about 50 cents per ton), and our results give a very decided advantage to the automatic continuous cylinder in the uniformity of the roast. It was found that ore which took one hour and three-quarters to pass through the cylinder was thoroughly roasted, so far, at least, as was necessary for amalgamation.

The chief objection to the cylinder was in the amount of flue-dust made, and that in a somewhat less degree is also the objection to any hand-rabbled furnace. The arsenic fumes are very dense, and when aided by a rapid current of air, they easily carry over dust and gold.

The question is not at all one of roasting the ore, for arsenical sulphurets roast much more easily, more quickly, and sinter less than simple sulphurets; but the important question—the only practical difficulty found in the treatment of these ores—is that of preventing a loss of extremely fine gold, which is mechanically carried over with flue-dust and arsenic fumes. This cause of loss, though it will probably always exist to a greater or less extent, does not appear by any means insuperable; but our tests have thoroughly convinced us that, both on the score of expense and loss in flue-dust, no hand-rabbled furnace is admissible. The automatic continuous revolving furnace, known in the Western States as the White & Howell furnace, and in England as the Oxland, is entirely satisfactory so far as expense is concerned; but without special precautions, it will make too much flue-dust. By taking out most of the shelves, or leaving only sufficient to turn over and not lift the ore (which when hot, runs like quicksand), the greater part of the loss which we encountered would, no doubt, be avoided. There are other modifications in the revolving cylinder which have suggested themselves; but as they have not been tried, they need not be mentioned here.

In Philadelphia, a revolving hearth, with fixed rabbles, and with a preheating furnace forming the flue from the revolving hearth, has worked well, and undoubtedly made less dust than the cylinder.

Of course, some of the gold which escapes is recovered by the re-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treatment of the flue-dust; but there would still be a loss, which should, and in a great measure undoubtedly can, be avoided.

The roasted ore was found to amalgamate with the greatest possible facility, 80 and even 85 per cent. of the gold contained in the roasted ore being obtained in regular work and with a very slight loss of mercury. There is no flouring of the mercury, and the gold is bright and very readily amalgamated.

Some of the roasted ore was treated by chlorination under pressure (Mears's process), and practically nearly the full fire-assay was obtained. Even including the loss in flue-dust in roasting in the revolving hearth, an ore which assayed less than $14 per ton *yielded, net in the bullion, 91 per cent. of the fire-assay;* so that it is thought that by care in roasting, from 93 to 95 per cent. of the gold in the concentrates can be regularly obtained. That the loss in concentrating will be very small, can be understood when it is considered that the concentration will not be made close. It is proposed to crush the ore in rock-breakers to from ½ to 1 inch size, screen in revolving screens which will size into say ¼ to ½ inch and ½ to 1 inch, which would then be jigged, the richer ore going to rolls, and thence directly to the roasting furnace without concentration, and the poorer going to other rolls, where it is crushed, and then jigged. It is thought that from ½ to ⅔ of the sulphurets, and consequently of the gold, will be obtained in the coarse jigging, and will suffer no loss in concentration.

The practical working of these ores I hope to give in another paper at some future time, when the works now building shall have given results on a large scale. The works for the Canada Consolidated Gold Mining Company are intended to treat from 100 tons to 125 tons a day.

Without going into the cost of mining and milling these ores, a subject which I hope to give, with large practical results, at a later day, I may say that a number of experts, taking from the books the figures of cost of such work as has already been done at the mines, have estimated at from $3 to $3.50 per ton of ore, as it comes from the mines, the entire cost of mining and milling. This cost is made up about as follows:

Mining, per ton of ore as mined,	$1 75	
Concentrating,	50	
Roasting,	20	= 60 cents per ton concentrates.
Chlorinating,	50	= $2 per ton roasted concentrates.
Contingencies,	55	
	$3.50 per ton.	

Labor is paid $1 to $1.25 per day; wood, $1.25 per cord; water-power will partly drive machinery. Supplies of all kinds are extremely abundant and cheap.

The ore carries as an average between $18 and $19 per ton in gold, and assuming a net yield in bullion of only 80 per cent., the net profit on the treatment of these ores is estimated at from $10 to $12 per ton.

ORE DRESSING AND SMELTING AT PRIBRAM, BOHEMIA.

BY ELLIS CLARK, JR., PHILADELPHIA.

THE mining town of Pribram is situated in Central Bohemia, on the western slope of the Heiliger Berg, 30 miles southwest from Prague. Birkenberg, the village in which most of the shafts and ore-dressing establishments are situated, is built on a mountain of the same name. It is about a mile from Pribram, is 1700 feet above the sea, and is surrounded by graywacke rocks of Silurian origin, which are intersected by greenstone dikes, and in the southerly, southeasterly, and southwesterly direction are bounded by granite. The graywacke formations consist on one side of graywacke sandstone and quartzite, and on the other of graywacke slates. These last are separated from the first in the immediate vicinity of the mines by a graywacke seam converted into clay. For many years this so-called clay seam (*lettenkluft*) was considered as a boundary of the ore deposits in both zones of graywacke. The graywacke formation is divided according to its hardness, structure, texture, and color, into fine, coarse, compact, slaty, whitish-gray, reddish-gray, and black graywacke.

The miner divides the formation into four divisions. The first or lowest division, which is in contact with the granite, consists of a fine-grained dirty gray slate; the second is a very fine to a very coarse schist, white to reddish-gray in color, and rich in quartz, but containing little mica; the third consists of a slate with a confused cleavage, which has a dirty gray, dark gray, and very often black color, and is often graphitic in its composition; the fourth consists of a fine to coarse-grained graywacke schist, of a grayish-white or reddish-gray color, and rich in quartz. The cleavage in all four divisions strikes from northeast to southwest, and the dip is sometimes northwesterly, sometimes southerly, and often vertical. All four zones are cut through by a great number of diorite and greenstone dikes and chimneys. The thickness of these dikes, which are of

plutonic origin, varies between sixty to ninety feet and one to two feet. The general direction of their strike is south, and they maintain a parallelism to each other. A very interesting geological feature is the contact relation between the zones of graywacke and the diorite dikes. No indication of any great geological disturbance, such as a shattering of the graywacke deposit or a decided contortion of the cleavages, is in any place noticeable. At many points the greenstone dikes are sharply separated from the graywacke, their selvages are smooth and even, and neither the greenstone nor the graywacke shows any indications of the contact influence of the other. This is especially the case where the graywacke is richest in quartz.

At other points, where the dikes cut through reddish graywacke schists, a change in these latter, caused by the selvages, is noticeable for many inches, and even feet. In such cases the graywacke becomes of a yellowish-brown color, a result of the decomposition of the iron pyrites that the rock contains. In many cases the two rocks are so closely joined that no contact seam is visible, the two appearing to be a single rock with a sharp and decided change in color and composition.

The greenstone dikes have played a very essential part in the formation of the somewhat younger mineral lodes, and undoubtedly were the original cause of the seams and fissures which have been subsequently filled by the ore deposits.

Besides the diorite dikes the four graywacke zones are intersected by a great number of lodes. These lodes generally make their appearance at the surface in the form of a gossan or iron hat (*eisener hut*), which extends to the depth of 240 feet and over before the precious ores and other minerals make their appearance. The lodes in general represent a great system, which consists of a large number of approximately parallel veins, with a southerly strike, distributed over an area of more than a mile and a quarter in length by three-quarters of a mile in width. The principal location of the Pribram lead and silver lodes is in the second zone of the graywacke, especially in the neighborhood of the northern boundaries of this section, not far from the previously mentioned clay seam, which separates the third zone (slate) from the second (Fig. 1, Plate I). Here the principal shafts are situated in a line bearing northeast and southwest. The thickness of the forty lodes that are at present worked varies from one inch to twelve feet, the average thickness being about two feet. In general the lodes have a diminished thickness in the coarse-grained graywacke and in the compact slate, while in

a less compact rock their thickness is increased. A very interesting geological feature is the close relationship and influence upon each other which exist between the lodes and the dikes and chimneys; not only do their extent and direction generally coincide, but the ore deposits frequently become for great distances regular contact lodes between the graywacke and the greenstone. In such cases the lodes are diminished in width, but are unchanged in quality. Occasionally the lodes penetrate and pass through the dikes, and also send out small branch lodes into them. Where the former is the case, it has been found that the lodes are generally larger in dikes of a yielding texture, while on the contrary very compact greenstone has a tendency to contract the lodes. The vein matter is similar to the pyritous galena formation in Freiberg, excepting that arsenical pyrites are absent, while spathic iron and some antimony ores are present. The gangue is quartz, calcspar, brown spar, dolomite, heavy spar, and spathic iron ore. Quartz and spathic iron ore are found in all the lodes, calcspar and dolomite very frequently, heavy spar and dolomite more seldom. Masses of country rock (horses) and clay are very frequent. Of the seventy-eight minerals found in the lodes, the following may be mentioned: Argentiferous galena; brown, and red zinc blende; white, black, green, and yellow galena; fahlerz; copper pyrites; bournonite; native silver; ruby silver; silver glance; iron pyrites; gray antimony; white, and red antimony; occasionally uranite; and rarely copper-nickel.

Of the minerals above mentioned, galena and blende are the most abundant. The galena contains from 0.07 to 0.094 mint pounds of silver and 75 to 83 pounds of lead in 100 pounds. Very often rich zones of native silver and ruby silver are met with; for example, in 1855, at the junction of the Wenzel and the Franzisci lodes a mass of ruby silver in ochrey brown iron ore, 800 pounds in weight, was discovered. It was considered a remarkable phenomenon that the brown iron ore should have reached so great a depth. The zinc blende usually contains 0.087 mint pounds of silver in 100 pounds. In general the texture of the lodes is massive; but a parallel striated texture, and, above all, a tendency to a symmetrical disposition of the minerals parallel to the walls, is especially noticeable in the Adalbert lode. In such cases, galena, blende, or quartz is generally the first layer next to the selvage; we conclude, therefore, that they are the minerals that were first deposited, by a process of infiltration, in the original fissure. The next layer consists of spathic ore, heavy spar, calcspar, brown spar, or again quartz, either with, or in alter-

nation with, films of galena and blende. The centre of the lodes is in general a cavity, the sides of which are lined with crystals. Very often galena alone, or galena in company with zinc blende, occupies the whole lode, in which case all of the gangue material disappears.

In cases where calcspar and brown spar, the youngest members of the lode, appear as its middle layer, galena, blende, and quartz are the oldest members; but, in other cases, these latter minerals appear in many places to be comparatively recent formations, since the remaining mass is very often traversed by small branches and leaders from them. Argentite and ruby silver are very often met with in calcspar. Native silver may be mentioned as one of the youngest products, and it is most frequently discovered at points where a decomposition has taken place.

The relative ages of the different lodes can be detected only at a few points, as great faults of one lode by means of another are very uncommon. Though the lodes, owing to the various strikes and dips, frequently meet and sometimes cross, yet they generally continue, after meeting, in a parallel direction, touching each other and possibly coalescing into a single lode (Fig. 2, Plate I).

It is noticeable, however, at the crossing-points, that one of the lodes does not continue in its original direction, but is moved a little laterally, making a slip of a foot or so, and continuing on the other side with the same strike and dip. This may be considered more as a result of the original fracture of the cleft than the result of a regular faulting. As a rule, the crossings exert neither a qualitative nor a quantitative influence on the materials contained in the lode, although sometimes rich crossing-points are met. Many of the lodes are of great extent, both in strike and in dip. The Adalbert lode, for instance, was worked 5100 feet along its strike, 2400 feet along its dip, and to a vertical depth of 2160 feet without showing any indication of decreasing in richness, or any particular change in the materials contained by the lode.

The lodes that have been most extensively worked are situated in the second zone of the Pribram graywacke, and it is on account of their tendency towards the south into the first graywacke zone that the mining has not been continued in this section. The several outcroppings and iron hats indicate, however, that in this zone, as well as the second, lodes occur. Workable ores have been found in abundance in the third (black slate) zone.

The history of these mines may be divided into three periods:

I. From the date of the earliest information to 1579.

II. From the absorption of the mines by the government in 1580 to the commencement of the Adalbert shaft in 1779.

III. From 1779 to the reaching of the 1000 meter level in 1876.

A detailed account of the mines at Pribram would too greatly extend the limits of this article, and therefore only a few items in regard to their operation can be given. The Adalbert shaft is the deepest in the world, measuring 1060 meters (3478 feet), or nearly two-thirds of a mile. Very little water is met with in any of the shafts, and the pumping machinery is almost ridiculously small when compared with the immense hoisting engines, which are of 300 horse power, have drums over 30 feet in diameter, and raise the ore from the bottom to the surface in the space of two minutes. For the last century the mines have been most carefully and systematically worked. The shafts and gangways are kept well in advance of the profitable workings, and a large amount of reserve ore is always on hand. The method of mining by overhand stoping is followed exclusively.

At the close of the year 1878 enough ore remained in the upper levels to keep the mills going for thirty-three years. The amount of material taken from all the mines in the year 1879 was 66,957 tons, from which 26,751 tons of galena were obtained, yielding 156,940 pounds of silver and 12,696 tons of lead, representing a value of $4,169,125. From 1876 to 1878 the mining capital employed was $186,786, or an average of $62,262 a year, during which time the works yielded $1,738,983, or an average of $579,661 a year, compared with $355,039 a year of the preceding period.

The number of men, women, and children employed in skilled and ordinary labor at the works amounts to 5177. They are paid at the rate of from 20 cents to 62 cents a day.

The buildings, together with the plant for the separation and concentration of the ores obtained from the various shafts, are as follows:

I. The Adalbert ore-dressing house in the immediate vicinity of the Adalbert shaft, containing two similar sets of revolving separating screens, twelve jigging machines, a washing trommel provided with a set of three revolving separating screens and a rotating picking-table, and three sets of Cornish rolls with their screens. In connection with the building there is also a basin or sump for the collection of the slimes resulting from the various operations, which is 283 square meters (3046 square feet) in area and 1.5 meters (4.9 feet) deep.

II. The Adalbert roll-house, provided with six sets of rolls and

revolving screens, four jigging machines, three Salzburger percussion-tables, and a sump 254 square meters (2734 square feet) in area and 1 meter (3.3 feet) deep.

III. The Adalbert stamp-mill, provided with forty-eight stamps, one Dingey mill, three sets of jigging machines, three Rittinger percussion-tables, eighteen Salzburger percussion-tables, and a sump 48 square meters (517 square feet) in area and 2.5 meters (8.2 feet) deep.

IV. The Anna ore-dressing house, provided with three rotating picking-tables, one stone crusher, two sets of rotating separating screens, seven Salzburger percussion-tables, three Rittinger percussion-tables, eight jigging machines, and a sump 84 square meters (904 square feet) in area and 2.5 meters (8.2 feet) deep.

V. The Anna roll-house, containing five sets of rolls, three jigging machines, two centrifugal pumps, and a sump 66 square meters (710 square feet) in area and 1.3 meters (4.3 feet) deep.

VI. The Anna stamp-mill, provided with 132 stamps, five jigging machines, eight Rittinger percussion-tables, thirty-five Salzburger percussion-tables, a plunger pump, and a sump 403 square meters (4338 square feet) in area and 1.3 meters (4.3 feet) deep.

VII. The Thinnfeld stamp-mill, with forty-five stamps, two sets of jigs, twenty-two Salzburger percussion-tables, and a sump 3000 square meters (32,292 square feet) in area and 1.5 meters (4.9 feet) deep.

VIII. The Lill ore-dressing house, containing a washing trommel provided with a set of three rotating separating screens, two jigging machines, a rotating picking-table, six Salzburger percussion-tables, two magnetic machines, two sets of crushing rolls, a small roasting oven, and a sump 67 square meters (721 square feet) in area and 1.5 meters (4.9 feet) deep.

IX. The Stephanie ore-dressing house, containing a washing trommel provided with three separating revolving screens, eight jigging machines, two Rittinger percussion-tables, and eight Salzburger percussion-tables.

X. The Stephanie rolling-mill, provided with four sets of rolls, three jigging machines, and one Rittinger percussion-table.

XI. The Stephanie stamp-mill, with thirty-six stamps, one jigging machine, and four Salzburger percussion-tables.

XII. The new rolling-mill at the Anna shaft.. Contrary to the former system of arranging the plant all on the same level, this building, like a new one in construction, is three-storied. The plant

consists of eight sets of rolls, the coarsest in the upper story, two separating trommels, seven sets of jigging machines, one plunger pump, one Heberle mill, ten Salzburger percussion-tables, and a sump 144 square meters (1550 square feet) in area and 1.5 meters (4.9 feet) deep.

ANNA ORE-DRESSING HOUSE.

The knockings (*grubenklein*) under 64 mm. (2.5 inches) in diameter are transported direct from the shaft to the sorting-house in cars and dumped into a large shoot, constructed of masonry, situated at one side of the building. This shoot is provided with two openings below, which communicate with a coarse rotating picking-table by means of an inclined cast-iron trough, which is supplied with warm water from the engine-room above.

The bottom of the trough consists of perforated cast-iron plates 0.15 meter (5.9 inches) wide and 0.80 meter (31.5 inches) long, the holes being 32 mm. (1.26 inches) in diameter, over which the knockings are raked by boys with a scraper of peculiar shape, called a *kratze*. The rotating picking-table (*rotirender tisch*), of which the details are shown in Fig. 3, Plate II, consists of a cast-iron perforated ring, A, 4.4 meters (14.4 feet) in diameter and 0.6 meter (23.6 inches) wide, which is secured by six arms of bar iron, B, to an upright shaft, C, moved by a screw and pinion wheel, D, and working in a foot-block, E. The ring is cast in segments, which are bolted fast to the arms extending from the centre-plate. The holes are 10 mm. (0.4 inch) in diameter on the top, and are made a little larger at the bottom so as to prevent pieces of material from being lodged in them. The table takes three minutes to make a revolution, and requires 0.064 horse power. Just before passing on to the picking-table, the material is still further washed by means of a shower of water.

By passing over the grate, the knockings are separated into two divisions, namely, such pieces as are above 32 mm. in diameter, which pass on to the coarse rotating picking-table, and such as are under 32 mm. in diameter, which fall on a second grate, the holes of which are 22 mm. (0.87 inch) in diameter. Here another division takes place, and pieces above 22 mm. in diameter pass to a fine rotating picking-table, while those under 22 mm. in diameter, together with the water (*lauterwasser*), pass into a receiver and are conducted to the separating revolving screens (trommels), situated in the jigging-house, which will be later considered.

The pickers, boys from eight to fifteen years of age, stand around

the rotating picking-tables and separate the knockings into two divisions, *wende* and waste rock (*berge*).

This *wende* consists of pieces of ore greater than 2.5 inches in diameter. The waste (*berge*) is loaded into cars and removed to the waste dump, while the *wende* is taken to separating-tables and there divided into three sorts: galena (*scheideerz*), ore for crushing (*mittelerz*), and ore for stamping (*pocherz*).

The *scheideerz* is further divided into good ore (*guteserz*), which goes direct to the smelting works, and middle ore (*mittelerz*), which is worked with the ore for crushing. The ore for stamping is loaded into cars and transported to the stamp-house.

The ore crusher is similar in general construction and details to the Blake crusher. Its jaws are 0.42 meter (16.5 inches) long, and 0.25 meter (9.8 inches) wide, and give two hundred bites a minute of 4 mm. (0.16 inch) each. The material passing through this crusher falls on a series of three sieves, suspended at an inclination of 28°, which receive an up-and-down motion of 40 mm. (1.6 inches) by being attached to the pitman of the crusher. The holes in the punched plate screen in the first sieve are 15 mm., in the second 10 mm., and in the third 1.5 mm. (0.59, 0.39, and 0.06 inch).

The product of a size under 1.5 mm. (*mehl*), which is about 4 per cent. of the material crushed, is concentrated on jigging machines, which will be referred to subsequently. The product between 1.5 mm. and 10 mm. (*gries*), which is 10 per cent. of the amount crushed, is likewise jigged. The product between 10 mm. and 15 mm. (*graupen*), which is 16 per cent. of the material crushed, is jigged, if rich enough, otherwise it is taken to the crushing-house. The size over 15 mm. (*überfall*) goes also to the crushing-house.

The several grades of material from the sorting-house, known as *quetscherz* (ore which requires to be crushed), are transported in cars and dumped into a shoot directly over the first pair of rolls. These rolls are of the form known as Cornish rolls, and consist of two cast-iron cores, on which steel shells, 0.468 meter (18.4 inches) in diameter and 0.316 meter (12.4 inches) wide, are wedged. One of the bearings is stationary in the frame and the other movable. The rollers are kept in contact by means of india-rubber springs or buffers, and are connected by means of cog-gearing with involute teeth adapted to the constant variation of the distance between the centres of the rolls, caused by the difference in size of the material crushed. A heavy rimmed fly-wheel is keyed to the power shaft; a small cog-wheel, gearing into a larger one, is keyed to the axis of the station-

ary roller. On the other end of this axis a cog-wheel is keyed, gearing into another cog-wheel on the axis of the movable roller. The automatic feed consists of a fixed sheet-iron hopper, under which is a spout made of heavy sheet iron, which receives a shock, caused by the striking of a shoulder on its under side against the fixed frame of the rolls, the motion being imparted by means of a small cam-wheel and rubber buffer. The sides of the rolls are provided with upright pieces of sheet iron for the purpose of preventing a scattering of the material coming from the feed. Running at the rate of thirty-six revolutions a minute, on *mittelkorn* measuring 12 mm. (0.47 inch) in diameter, 2 horse power is required, and on material measuring 26 to 39 mm. (1.02 to 1.53 inches), 5 horse power. The power is imparted to the cam-shaft of the feed either by means of belting or by cog-gearing.

The ore and water from the sorting-house flow on to a revolving screen, and is separated into three sizes—9 mm., 12 mm., and 16 mm. (0.35, 0.47, and 0.63 inch). The stuff under 9 mm. passes into a second revolving screen, where it is likewise divided into three sizes —6 mm., 4 mm., and 2 mm. (0.23, 0.16, and 0.08 inch). The screens are cylindrical, 1 meter (3.28 feet) in diameter and 3.3 meters (10.83 feet) long. They make from eighteen to twenty revolutions a minute, are set at an angle of $2\frac{1}{2}°$, and require together 1.17 horse power.

The ore to be crushed passes "dry" through the coarse rolls, and the crushed material passes over an inclined sieve of 0.5 mm. (0.02 inch) mesh; the stuff passing through this sieve is conveyed by means of an endless screw, situated in a trough under the floor, to an elevator (*paternosterwerk*). This elevator consists of a leather band 0.24 meter (9.45 inches) wide, with thirty-two sheet-iron buckets attached, passing over pulley-wheels above and below, which make sixteen revolutions a minute. The lower pulley-wheel is keyed to the axis of the endless screw. The screw is 4 meters (13.12 feet) long, 0.316 meter (12.44 inches) in diameter, and 0.1054 meter (4.15 inches) pitch. The elevator raises the material to the hopper of a revolving screen situated on the floor above. The material over 0.5 mm. (0.02 inch) in diameter is thrown by hand into a fine roller, the crushed product from which is also conducted to the screen in the upper story by means of the endless screw and elevator. This revolving screen is 3 meters (9.84 feet) long, 1 meter (3.28 feet) in diameter at the larger end, and 0.632 meter (2.07 feet) at the smaller. The screen, screw, and elevator require 1.29 horse power.

This revolving screen separates the material into four divisions, the first and second (the finest) being together further separated on a pounding sieve (*stossrätter*), which is simply a sieve 5 feet long by 18 inches wide, with a perforated copper-plate bottom of 0.5 mm. (0.02 inch) mesh, suspended by iron hooks in a stout wooden frame, and receiving a shock, imparted by an arrangement similar to the one already described in connection with the automatic feed of the rollers.

The stuff passing through the sieve, containing 0.014 per cent. silver, 21 per cent. lead, and 5.4 per cent. zinc, is, owing to its exceedingly fine state of division, sent directly to the smelting works. The coarser stuff passing away from this sieve is concentrated in a jigging machine, with 0.5 inch stroke, working at 180 strokes a minute. The object of this separation on the *stossrätter*, before treating the material directly on the jig, is to bring about as good a separation as possible between the very finest (*mehl*) and the next larger size (*gries*), since by the omission of this operation before jigging considerable loss would be experienced by the passing away of the very finest stuff with the water from the jig. For this purpose the *stossrätter*, with its motion given by shocks, is found to work better than the revolving screen.

The third division coming from the revolving screen is jigged in a machine making 160 strokes of 19 mm. (0.75 inch) a minute, and the fourth product, that passing off the screen, falls through a vertical shoot to a roller below, in front of which is an inclined sieve of 1 mm. (0.04 inch) mesh. Here two products are obtained: that portion passing through the sieve is carried by the endless screw, before mentioned, to the elevator, and again to the revolving screen, while the coarser portion is removed to a roller in an adjoining room, to which a three-sieved revolving screen is attached, which divides the material into four sizes, all except the largest being jigged. This latter is removed to an adjoining fine roll, the crushed product from which likewise passes through a three-sieved rotating screen, with meshes 3, 2, and 1 mm. (0.12, 0.08, and 0.04 inch) in size, all the material obtained being jigged. The finest product is worked with the finest product resulting from the former revolving screen on a jig making 160 strokes of 0.75 inch a minute, and the two coarser products, with the two coarser products from the other screen, are jigged together in a machine working with 120 strokes of 1 inch a minute.

The room in which the coarse rollers and the elevator are situated contains also three continuous working three-sieved jigging machines,

in which the separation takes place through the sieves. The sieves are situated on the same level and are divided by a wooden partition 50 mm. (2 inches) high, surmounted by a piece of sheet iron of a semi-cylindrical form, which by means of two set screws may be elevated or depressed, thus regulating the passage of the material over the partition. These jigs are of wood, with round bottoms, and have an eccentric so constructed that the stroke can be readily changed.

The material coming from the sorting-house before mentioned passes into another revolving screen; the coarsest is worked on a *stossrätter*, and the two middle products, as well as the four products resulting from the fine screen are treated on jigs. Some of this material coming from the sorting-house is passed into a similar revolving screen, the finest portion from which passes over an inclined fixed screen, and is divided into two parts, the coarser of which is jigged with the second product from the finer of the first mentioned revolving screens, and the finer is jigged with the finest or first product from the same screens. The second and third products of the revolving screen are jigged with the third product of the coarser of the pair of revolving screens. The fourth or coarsest product is worked on a *stossrätter* with the coarsest product resulting from the coarser of the pair of revolving screens. The pair of classifying revolving screens make 18 to 20 revolutions a minute, are cylindrical in form, slightly inclined, 1 meter (3.28 feet) in diameter, 4.187 meters (13.74 feet) long, and require together 1.17 horse power.

The new rolling mill at the Anna shaft, as before mentioned, is a three-storied building. The material is conveyed in cars to the two sets of coarse rolls situated in the upper story, by means of an inclined plane. The crushed product passes through a shoot to six sets of fine rolls in the story below, 0.312 meter (12.28 inches) wide and 0.465 meter (18.31 inches) in diameter, which makes 15 revolutions a minute. From the rolls the crushed product passes into two cylindrical separating screens, each of which is 1 meter (3.28 feet) in diameter and 3 meters (9.84 feet) long, with 2, 4, and 6 mm. (0.08, 0.16, and 0.24 inch) mesh, and works on friction rollers. The material over 6 mm. is conveyed by transport screws to a bucket elevator, and again passed through the fine rolls, while the 4 mm. and 6 mm. stuff passes through shoots to bedded three-sieved continuous jigging machines situated on the floor below.

The 2 mm. stuff is concentrated on two fine jigging machines, making 190 strokes of 2.6 mm. (0.1 inch) a minute. The 4 mm.

stuff is concentrated on two middle jigging machines, making 175 strokes of 3.9 mm. (0.15 inch) a minute. The 6 mm. stuff is concentrated on two coarse jigging machines, making 160 strokes of 8 to 10 mm. (0.3 to 0.4 inch) a minute.

These jigging machines are constructed and worked in the usual way, except that the material from the rolls, instead of passing directly to the jigs, is first mixed with water and then passes into a small *spitzkasten* (pointed hopper) from which the heavier particles pass through a short wooden pipe to the jigging machine, while the lighter particles, together with the overflow of water, pass away from the *spitzkasten*, and are conducted through a series of catchpits, the settlings from which are concentrated on Salzburger percussion-tables. The jigging machines concentrating the 4 and 6 mm. stuff are provided with moderators on the first and second sieves in order to remove the coarser lead particles.

THE MIDDLE JIGGING MACHINE.

The detailed construction of this machine is shown in plan and section in Fig. 4, Plate II. At the head of the jig is a self-feeding apparatus, A, worked by a rubber buffer and a cam, C, receiving its power from the shaft, S. The sieves of 3 mm. (0.12 inch) mesh rest on a slightly inclined wooden grate, which is 36 inches long and 18 inches wide. The jig boxes, D, below the sieves are pyramidal in shape, thus preventing the accumulation of material on the sides, as frequently occurs in the case of round bottoms. The piston is constructed of 4-inch timber, its upper surface being on the same level as the sieve, which is thus always covered, preventing the swashing of water and the sucking down of air. Each piston is suspended by connecting-rods from two eccentrics, the stroke of which can be regulated at pleasure between the limits of 0 and 1.5 inches. The water used in the process passes into the water box, E, one side of which acts as a screen, thus preventing particles of material from passing into the pump by which the water is lifted out. This pump consists of a propeller keyed to the foot of a vertical axle, which receives a rapid motion of 220 revolutions a minute by means of the friction wheels, F and G; it lifts the water from 8 to 12 inches to a sieve for the purpose of freeing it from all foreign matters, such as chips, etc. The water is then conducted through the distributing box, H, to the piston boxes of the jigs. During the operation a small quantity of water is necessarily lost; this is replenished from time to time by mean of fresh water admitted through the pipe, I. The surface of the

friction wheel, F, is covered with leather so as to produce a better friction, and the wheel, G, is slightly bevelled. These two wheels can be brought into closer contact by means of a screw cut on the power shaft in a direction contrary to the motion. The sterile portion of the material passes into the foot of a cylindrical cast-iron trough, set at an angle of 25°, containing an archimedean screw set in motion by spur gearing, by which it is lifted into a car. The diameter of the screw is 8 inches, and that of its axis 2 inches; it has a pitch of 4 inches, and makes 40 revolutions a minute. The material passing through the screen accumulates in the boxes, D, from which it is withdrawn from time to time into receivers. The coarser material remaining on the screens forms a bed, the thickness of which can be regulated by raising or lowering, by means of thumb-screws, a sheet-iron cylinder, 10 inches high and 6 inches in diameter. When a sufficient amount of the enriched material has collected on the sieve bottom, it is drawn off through the discharge-pipes, P, which are from 1.5 to 2.5 inches in diameter.

At the bottom of this discharge is a valve arrangement (moderator) by means of which the outflow of material is regulated. The material from the first sieve passing through the discharge-pipe, as well as that passing *through* the sieve, is sent to the smelting works. The material passing through the discharge-pipe of the second sieve is sent to the crushing mills, while that passing through the sieve is reconcentrated on fine jigging machines. Stuff from 4 to 12 mm. (0.16 to 0.46 inches) in diameter (*wäschgraupen*) is generally worked on this jig. Material of 4 mm. requires 160 strokes of 1 inch a minute, and produces 17 cubic feet of concentrated products an hour. The propeller-pump lifts 3.4 cubic feet of water a minute. Material of 12 mm. requires 160 strokes of 1.5 inches a minute, and produces 27 cubic feet of concentrated material an hour. In this case the pump lifts 6 cubic feet of water a minute. In both cases 0.75 horse power is required.

The sterile material which passes away from this jig (*berge*) is exceedingly poor, containing only from 0.25 to 0.37 per cent. lead, and 0.004 to 0.005 per cent. silver. The amount of water wasted is from 0.75 to 1 cubic foot a minute. In the case of the 4 mm. stuff, the concentrated material from the discharge-pipe of the first sieve contains 0.567 per cent. silver, and 81.62 per cent. lead; that from the discharge-pipe of the second sieve, 0.046 per cent. silver and 3.12 per cent. lead.

In the case of the 12 mm. stuff, the concentrated material from the

discharge-pipe of the first sieve contains 0.61 per cent. silver and 72.75 per cent. lead; that from the discharge-pipe of the second sieve 0.05 per cent. silver and 4.37 per cent. lead. The 12 mm. stuff before concentration contained 0.042 per cent. (13½ oz. to ton) silver and 4.25 per cent. lead.

The Anna stamp-mill (*pochwerk*) consists of four buildings: 1st. Stamp-house proper. 2d. Jigging-house. 3d and 4th. Slime concentrating-houses. The power used in these four buildings is supplied by a Wolf engine of 80 horse power, situated at the lower end of the stamp-house, and a Schwamkrug turbine of 60 horse power, situated at the upper end of the jigging-house, on a level with the Joseph II adit. The water supply for the turbine is obtained from the overflow of the slime-pits of the Adalbert concentrating-house, and has a fall of 137 feet. As a constant supply of water from this source cannot be relied upon, the shafting for the transmission of power is so arranged that the stamp-mill may be run by the engine alone, and the remaining buildings by the turbine in case there is sufficient water; or, should the water supply entirely fail, the engine is capable of supplying the necessary power for operating all four buildings. The power is transmitted from the main-shaft, extending the entire length of the stamp-house, to the other buildings by means of endless wire ropes, for which purpose the condemned ropes from the various shafts are brought into requisition.

STAMP-HOUSE.

The stamps, 132 in number, are arranged in two rows, extending the entire length of the building. In designing the stamp-house it was intended to provide for the laying down of 10 stamp-mills, each mill consisting of 4 sets of 3 stamps each. During the past few years, however, experiments with various forms of stamps have been tried, so that in the fall of 1880 four styles of stamps were in use, namely, 96 ordinary stamps with square stems of timber, 30 stamps with square steel stems, 3 California round-stemmed revolving stamps, and 3 stamps with open (*geschlitzte*) stems. The stems of the ordinary stamps are of beech, 13 feet long and 6 inches square; the stamp-heads are of wrought iron, also 6 inches square, 9 inches high, and weighing, on an average, 100 pounds. The tappets are of cast iron, set into the stem, and secured there by wedges below and above, thus permitting the change of the position of the tappet as necessitated by the wear of the stamp-head. The stem, tappet, and shoe weigh together about 207 pounds. The stamps

have a lift of 8 to 10 inches, fall at the rate of 60 blows a minute, and are capable of crushing 101,250 pounds of ore in 24 hours, requiring 0.4 cubic foot of water a minute for each stamp. The iron cams, which are keyed to the wrought-iron cam-shaft, are double, as shown in Fig. 5, Plate II. The cam-shafts are 14.13 meters (46.4 feet) long and 0.11 meter (4.4 inches) in diameter, and weigh 800 pounds. They are provided with key seats, for the fastening of the cams in their places, and are supported by three cast-iron brackets, which carry the journal boxes, and are bolted to the shaft frame.

The main shaft, running parallel to the cam-shafts, is connected with them by cog gearing, and extends the entire length of the building, passing through the wall and carrying a 12-foot sheave-wheel at its extremity, which serves to transmit the power by wire rope to corresponding sheave-wheels at the other three buildings. The water necessary for the stamps comes from the slime-pits of the Anna concentrating-house, and is raised into a large iron tank situated in the stamp-house, by means of a centrifugal pump, receiving its power from the steam-engine. This pump makes from 500 to 600 revolutions and lifts from 40 to 50 cubic feet of water a minute. In case the supply from this source be insufficient, a portion of the overflow from the ten reduction-boxes (*spitzkasten*) adjoining the stamp-house is used. From this reservoir the water is delivered through distributing troughs to the batteries.

It has been ascertained by experiment that better results are obtained when the *pocherz* (ore for stamping) is mixed with about one-half its quantity of *mittelerz* from the Adalbert concentrating-house.

The style of battery exclusively used is known as the *Stausatz*, or Stay battery, as devised by Rittinger and shown in Fig. 6. The essential feature of this battery is a damming of the water before the screen by means of a coffer-box, for the purpose of dislodging by the swash of the water all foreign matters, such as chips, etc., which tend gradually to close up the meshes of the screen. This coffer-box has sloping sides, and is provided with a stop-cock at its lower end, by which the height of the water in the mortar can be regulated, and which also serves for the removal of the crushed product. The stamp-bed consists of a die and bed-plate, both of cast iron. The bed-plate is 0.68 meter (26.77 inches) long, 0.120 meter (4.72 inches) thick, and 0.20 meter (7.87 inches) wide, the die being somewhat smaller in section, both extending the entire length of the mortar. The bed-plate rests on blocks of wood set on end, which are sup-

ported on cross-sills. The die does not fill the entire space of the mortar, but is secured by wedges, so that it can be turned when the upper side has become worn, and eventually can be easily removed. The screen is of brass wire, with 2 mm. (0.08 inch) mesh, its frame being of wood, 0.675 meter (26.58 inches) long and 0.32 meter (12.6 inches) wide.

In the case of the ordinary wooden stamps, the ore from the shoot, situated in the rear of the battery, passes through an automatic feed to the central stamp. This automatic feed consists essentially of a stout wooden trough, having an inclination nearly corresponding to that of the bottom of the shoot, supported by a timber extending between two of the uprights of the shoot-frame. A cross-piece is mortised into the lower end of the trough, which carries a vertical stick of hard wood, about three inches in diameter, the upper end of which receives a blow, when the stamp is "hungry," from the back projection of the tappet through the stamp-stem. This style of feed is exceedingly simple and effective. On the front and rear of the shaft-stem cast-iron guides triangular in section are bolted, which slide in corresponding slots, serving the purpose of keeping the stems in position.

The stamps with square steel stems are disposed in six batteries of five stamps each. The details of the battery do not differ from those already described; the shaft stems are of Bessemer steel 0.052 meter (2.05 inches) square, and 3.35 meters (11 feet) long, and weigh 142 pounds, being somewhat bevelled at the lower extremity so as to fit into the shoe. In November, 1879, the form of the stamp-heads was changed from a square to a rectangular section, after the pattern adopted at Clausthal in 1872. By this arrangement space is obtained for two more stamps, representing an increased working effect of 60 per cent., without necessitating an increase in either the amount of water, power, or size of battery, and materially diminishing the tendency of the stamp-heads to beat out hollows (*napfpochen*) in the dies. The shoes are of Bessemer cast steel, weighing 96 pounds, 0.184 meter (7.24 inches) by 0.105 meter (4.13 inches) in section, and 0.37 meter (14.57 inches) high, and are cast with a conical socket 0.17 meter (6.69 inches) deep for the reception of the tapered end of the stamp-stem, which is secured in its place by means of thin pine wedges. The tappet as shown in Fig. 5 is of cast iron, with a projection on the inner side, which fits into corresponding notches cut in the stem of the stamp, and is attached to it by means of a wrought-iron ring tightened by an iron wedge. This method of securing the tappet has been found exceedingly satisfactory.

The stem, tappet, and shoe together weigh about 278 pounds. These stamps have a lift of from 0.208 to 0.260 meter (8.2 to 10.2 inches), and make 60 blows a minute; a set of five crushes 5000 to 5600 pounds in twenty-four hours, requiring 0.1 cubic foot of water a minute for each stamp. The arrangement of the guides is the same as that shown in Fig. 5.

The open-stemmed (*geschlitzte*) stamps are shown in detail in Fig. 6, Plate II. At present a battery of three such stamps is in use. The essential advantage of this form of stamps is that the stem is lifted directly in its line of gravity, thus tending to diminish not only the friction exerted by the working of the cam on the tappet, but also that of the stem in the guides, a saving both in wear and tear and in power. The stems are of wrought iron, 0.052 meter (2.05 inches) square and 3 meters (9.84 feet) long, and weigh 188 pounds. The bottom of the stem is bevelled and fastened to the shoe in the manner already described in the case of the square steel-stemmed stamps. The sides of the open portion are 0.03 meter (1.18 inches) thick, 0.07 meter (2.76 inches) wide, and are pierced with holes for the axle of the roller, which as shown in Fig. 6 is stationary, allowing the roller to revolve about it. Formerly the roller and its axle were screwed together and revolved as one piece, but this was not found to work as satisfactorily as the method just described. As will be observed from Fig. 6, the opening in the stem of the middle or feed stamp is made somewhat longer than those of the other two, thus permitting the introduction of a piece of hard wood, which, when the stamp becomes "hungry," strikes upon the shorter projection of the angle iron (*trogknecht*), H, communicating an oscillating motion to the suspended feed-trough, I. The shoot opening into the feed-trough is furnished with sheet-iron guides, and the front is provided with a sliding door for the regulation of the discharge of ore on the automatic feed-trough. The shoe, weighing 112 pounds, has the same shape as that already described in the square steel-stemmed stamps. The stamp-head, stem, and roller weigh together 304 pounds. In 1865 a set of three California revolving stamps was introduced, which has since met with great favor. The stem is of round iron, 0.06 meter (2.36 inches) in diameter, and tapering at its lower end so as to fit into the socket in the top of the shoe. The stamp-head as shown by Fig. 5 is cylindrical in form, 0.16 meter (6.3 inches) in diameter, and 0.39 meter (15.35 inches) high. It is made of cast iron, is strengthened with a wrought-iron band at the top, and weighs 200 pounds.

The cams are the same as those used for the other stamps, except that the end of the lifting surface is somewhat bevelled, as shown in Fig. 5, so as to facilitate the revolving of the stems. The stamps are held in position and guided into the mortar by cast-iron guides, as shown in Fig. 5, which are situated above and below the tappet. The method of feed is the same as that already described in the case of the square steel-stemmed stamps. One of these stamp-heads lasts about three months and wears down very evenly.

The stamped ore and water (*trübe*) is conducted from the stamp-house to a series of ten reduction-boxes (*spitzkasten*), situated directly back of the stamp-house on a lower level. These spitzkastens, constructed of heavy timber, have the form of an inverted pyramid, 15 feet long, 8 feet wide, and 9 feet 2 inches deep, at the apex of which a wooden box (*fussstück*), connected with the spitzkasten by means of a short pipe, is attached. This *fussstück* is about 18 inches long and 4 inches square; it is provided at one end with a bent iron pipe, serving for the discharge of the material settling in the spitzkasten, and furnished with an aperture at the other end for the purpose of cleaning when choked; this aperture is closed by a plug when the spitzkasten is in operation. By means of this series of ten spitzkastens, the ore and water (*trübe*) is concentrated to one-third of its original volume. The concentrated material is conducted through a trough to the jigging-house, and the overflow, *i. e.*, the remaining two-thirds, is led to the slime-concentrating buildings, or, in case of a scarcity of water, a portion of it is raised by means of the centrifugal pump to the tank in the stamp-house as before described. The jigging-house, situated on the same level as the spitzkastens, and about 30 feet distant, contains two similar sets of apparatus arranged along the entire length. Each set consists of five spitzluttes, two sets of four-sieved fine jigging machines, four continuous Rittinger stossherds, four Salzburger stossherds, three spitzkastens, and an extra three-sieved fine jigging machine. There is also a system of canals leading to a settling pit (*sumpf*) situated outside the building, for the concentration of slimes resulting from the various operations.

A tramway extending along the entire length of the building on each side, and connected with the waste dumps, and also with the adjoining slime-house, facilitates the transportation of the concentrated products and the waste material. The concentrated product from the spitzkasten passes for classification into a spitzlutte, the construction of which is shown in Fig. 7, Plate II. The prin-

ciple of this apparatus is the classification of material by means of an ascending column of water. Its essential features consist of a wedge-shaped box, suspended by two hand screws, by means of which it can be raised or lowered in the cavity of a similar wedge-shaped box, thus leaving a space between the parallel sloping sides of the wedge, the ends of the wedge fitting closely against the perpendicular sides of the box. The interior of the outer box is brought to an apex near its bottom by means of two small triangular blocks of wood fitting against the sides of the wedge. This apex is connected by means of an iron pipe, Q, with a so-called foot-piece (*fussstück*), R, which consists of a wooden pipe, one end of which communicates with the pipe, G, for the admittance of clean water (*lauterwasser*), and the other end with a similar wooden pipe, N, (*austragrohr*), for the discharge of the heavier particles entering the foot-piece. The concentrated product from the reduction-boxes entering at A, flows down the space B, comes in contact with the ascending column of water from the foot-piece through the iron pipe, Q, so that only the heaviest particles find their way into the foot-piece. The lighter particles aided by the ascending flow of water pass up the side, H, and are conducted through a gutter to another spitzlutte similar in construction to the one just described. The coarser and heavier division of the material coming from the spitzlutte passes directly to a four-sieved jigging machine, similar in construction to the one already described. These machines work with 160 strokes of 8 mm. (0.31 inch) a minute, the separation taking place through the sieve, which is made of brass wire of 0.47 mm. (0.018 inch) mesh and supported by a perforated heavy sheet-iron plate with holes 2.5 mm. (0.1 inch) in diameter, which is covered with a bed of iron granules and acts the part of a sieve, the *schlich* (fine stuff ore) passing through both this bed and the sieve. These jigs require 4.5 cubic feet of water a minute. From the first sieve of the jigging machine a pure product is obtained, consisting of galena, which is transported directly to the smelting works. Through the second sieve a product rich in galena, but containing a small quantity of zinc blende, is obtained, which is likewise sent to the smelting works. From the two other sieves, a more or less enriched product (*mittelerz*) consisting of zinc blende and *berge* is obtained, which is thrown into the hopper at the head of the jigging machine, to be rejigged in connection with the mixed ore and water from the spitzlutte.

The water that passes through the sieves into the receivers is conducted through a series of channels (*gerinne*) to the settling pits.

That portion of the material which passes off the fourth sieve (*berge*) is conducted through an inclined trough into a revolving screen (*trommel*), conical in shape, 1.5 meters (4.9 feet) long, 0.7 meter (27.6 inches) in diameter at the large end, and 0.55 meter (21.6 inches) at the small end, making 18 revolutions a minute. This screen is of heavy perforated copper-plate, the holes being 1.5 mm. (0.06 inch) in diameter.

The fine material passing through the revolving screen is further concentrated on percussion-tables (Salzburger stossherds), or is rejigged on the extra three-sieved jigging machine, and yields three products: the first, a finely divided galena (*bleischlicht*), which goes to the smelting works, and a second and third, which are together rejigged. The coarse material passing from the screen is loaded into cars and removed to the waste dump.

The fine portion of the material overflowing from the previously described spitzlutte circulates through a series of five spitzluttes similar to the one mentioned, representing a surface of 4.03 square meters (43.38 square feet) and a depth of 1.3 meters (4.3 feet), and from thence through a series of three spitzkastens to the sump.

The heavier particles coming from the second spitzlutte are likewise concentrated on a four-sieved fine jigging machine, the resulting products being essentially the same as those won on the first four-sieved jigging machine. The heavier particles coming from the third, fourth, and fifth spitzluttes, as well as from the first spitzkasten, are treated on corresponding and adjoining continuous Rittinger percussion-tables. In each instance three products are won, the first consisting of a finely divided galena (*bleischlicht*), a middle product (*mittelerz*) which is reconcentrated on percussion-tables (Salzburger stossherds), and waste (*berge*), which is loaded into cars and goes to the dump. The various machines in the building obtain their power from two lines of shafting running the entire length of the building and connected by belts; one of these lines is directly connected with the sheave-wheel on the outside of the building.

The *trübe* or overflow from the several jigging machines is collected in a reservoir (*gerinne*), and lifted by means of a centrifugal pump into a trough leading to the percussion-tables. This centrifugal pump, making 490 revolutions, and lifting 56 cubic feet of *trübe*, water, and slime a minute to a height of 2.8 meters (5.9 feet), requires 7.68 horse power. The distance from the centre of the spindle to the end of the vanes is 0.22 meter (8.66 inches), the vanes are 0.12 meter (4.72 inches) wide, and the discharge-pipe is 0.18 meter (7.09 inches) in diameter.

The two buildings for the concentration of the slimes (*schlämme*) are situated on a somewhat lower level than the jigging-house, and each contains the same style of plant; the upper one having fifteen, and the lower twelve Salzburger stossherds. The slimes are removed from the sump to the concentrating-house by means of small cars and a railway, and dumped into shoots entering the upper side of the building. Owing to the thick and viscous condition of the slime it must be agitated with water, in order to obtain the regular and constant flow that is necessary for the proper working of a percussion-table. For this purpose an apparatus (*rührgump*), as shown in Fig. 8, Plate III, is used. The slime to be concentrated on the percussion-tables is shovelled into the oblong iron box, A, into which water is admitted, and the mass is thoroughly agitated by the revolving rake, B; the shaft to which the rake is keyed is provided with stuffing-boxes, C, in order to prevent a loss of material. In connection with the agitating-box there is a rotating sieve (*trommel*), D, which has for its object a separation of the slime from all foreign material, such as chips, grass, etc., which, by coming on the table, would tend to produce an uneven surface, and therefore an imperfect separation of material. The slime passing through the meshes of the sieve is collected in a semi-cylindrical sheet-iron trough, E, from which it is conducted through a gutter to the distributing board, situated at the head of the percussion-table. The power is transmitted to the shaft of the revolving rake by a belt and pulley, F, and from this shaft to the sieve by a cog-wheel or friction-bearing, G. The rake makes about 15 revolutions a minute. One of these "gumps" supplies two percussion-tables, weighs 1315 pounds, and costs $158. Ten percussion-tables are supplied with "gumps," like the one described, for the working of the raw material from the sump.

Eight percussion-tables have "gumps" without revolving screens; while seven are simply supplied with boxes into which the material is shovelled and washed on to the distributing-board by a stream of water. These fifteen are used for the second concentrating of the slime after it has been worked on the first ten percussion-tables. In both buildings the power is supplied to the tables and "gumps" by an overhead line of shafting, extending the entire length of the building and connected with the large sheave wheels on the outside, previously mentioned in connection with the transmission of power by wire ropes. The supply of water necessary is drawn from a main pipe extending along the building at the rear of the "gumps." A line of railroad runs in front of the percussion-tables for the hand-

ling of the concentrated and waste products. At one end of the building an elevator is situated serving for the transportation to a higher level of the concentrated products resulting from the two buildings. By each operation on the percussion-table three products are obtained, namely, first, second, and third (*ober*, *mittel*, and *unterschaufel*); these products are collected separately and reworked on adjoining tables, giving as before three grades; the first of which, in this case consisting of pure *bleischlicht* (galena finely divided), is delivered to the smelting works; while the second and third are treated a third time, giving also a product for the smelting works. The number of times the resulting products are treated, the inclination of the tables, the number of blows a minute, and the amount of water required, naturally depend upon the original condition of the matter under treatment. The overflow from the percussion-tables is conducted through a trough immediately in front of them, extending the length of the building. The deposit in this canal is collected and sent to the smelting works, while the water is used over again.

Fig. 9, Plate III, represents the Rittinger continuous, lateral working, percussion-table (*stossherd*). The frame of the table is substantially constructed of angle or cast iron, and may be covered with either wood, marble, slate, or cement. When wood is used a further covering of rubber cloth is necessary. This latter combination, *i. e.*, wood and rubber cloth, is most common. A heavy beam of wood (*zunge*), A, is bolted to the middle of the under side of the frame, projecting some distance beyond it on each side. The table is suspended from four iron standards by means of iron hooks, B, and has a motion imparted to it by means of a steel spring, F, and a cam, C, which is keyed to the power-shaft, D, which carries also a fixed pulley, E, and a heavy-rimmed fly-wheel, F. The spring and cam are shown in detail on a larger scale in the same figure.

The shock necessary for the working of the machine is given by the striking of the heavy wooden beam against the wedge-shaped block of hard wood, G. The table is divided into two parts by means of a strip of wood, I (similar strips being placed on the sides to prevent the overflow of the material), and can have its slope regulated by means of the screws, J. The material to be concentrated is admitted at the right-hand corner, K, to the table, through a small zinc box, the object of which is simply to prevent wear by the constant attrition of the particles of ore. The water distributors are provided with small triangular blocks of wood, for the purpose of

giving an even and regular flow to the clean water supply. On account of the inclination of the table, and the lateral percussion it receives, the heavier particles of ore form themselves into the curved lines, M; the lighter and more sterile portions pass in a straight line directly off the table; while the middle products form a series of lines of greater or less curvature, according to the richness and specific gravity of the material.

At the foot of the table troughs are placed for the reception of the separated material; these are provided with small zinc boxes, which are movable, so that their positions can be changed to correspond with the lines of division of the material. This arrangement is a decided improvement over the former method, in which short strips of wood were secured to the foot by means of a thumb-screw, and which could be turned at various angles so as to correspond with the curves of the material. In the working of these tables the observation of several essential points is necessary. The proper inclination of the table, the amount of clear water to be admitted, the tension of the spring, the amount of stuff admitted to the table, the velocity of the current over the table, and the proper position of the small zinc receivers at the foot, are all conditions which depend entirely upon the nature of the material to be treated. As previously mentioned, various methods for obtaining a smooth surface have been resorted to. In the spring of 1879 experiments were made with percussion-tables constructed of iron, after the pattern of the Humboldt Manufacturing Company in Kalk, bei Deutz, am Rhein. They consist of two cast-iron plates 2.529 meters (8.3 feet) long, 1.21 meters (3.97 feet) wide, and 20 mm. (0.79 inch) thick, joined together by bolts, and strengthened by ribs on the under side, weighing 1700 pounds. The heavy beam of wood is bolted to flanges cast on the under side of the plates. The smooth surface required is obtained by the planing of the plates on the upper side, they being subsequently painted white, in order to make the curves of the material more apparent. Their cost is $408.

A thin piece of sheet-iron is placed between the two plates, with the object of dividing the table into two parts, as was done by the strip of wood when the table was made of other materials. Raised edges of wood, 26 mm. by 26 mm. (1.02 inches) on the cast-iron table, prevent the material from working off at the sides. The object in making these plates 20 mm. thick is, that they may be planed once or twice when the surface is worn.

Previous to the trial with planed iron plates, experiments were

made with angle iron frames covered with wood on which marble slabs, 2.529 meters (8.3 feet) long, 1.264 meters (4.15 feet) wide, and 40 mm. (1.57 inches) thick, were laid. The iron frames weighed 702 pounds, costing $176, the marble plates weighed 696 pounds, costing $200; their setting cost $34, making the complete cost of a percussion-table with marble plates $410. The weight, when ready for working, is 1910 pounds. A comparison of the working of the marble and iron tables is shown in the following tables:

MARBLE TABLE.

	Weight Dry, lbs.	P. ct. Ag.	P. ct. Pb.	Holding Silver, lbs.	Holding Lead, lbs.
Schlicht,	936	0.318	63.	2.976	590
Middle product,	1956	0 097	8.5	1.897	166
	2892	0 415	71.5	4.873	756

IRON TABLE.

Schlicht,	834	0.317	64.	2.644	534
Middle product,	1830	0.129	13.	2.360	238
	2664	0 446	77.	5.004	772

In each case 24,000 pounds of the same material (*mehl*) were used. By this careful experiment the advantage of the iron tables over those of marble was made apparent. The less effective working of the marble tables was owing in a great measure to the too smooth surface. Another advantage of the iron tables is their great strength, and diminished liability to fracture. They also have a value as old metal when too much worn to be further used, while the marble when broken has a value of only $6.

If the surface of the table be too smooth, and the current of water improperly regulated, an imperfect working of the material results, causing the rich particles (*bleischlicht*) to pass off with the middle and waste products.

By the working of these tables three products are won: an exceedingly fine galena, which goes to the smelting works; a second more or less enriched product, which, according to its quality, is passed over the percussion-table a second time, or sent direct to the smelting

works; and a third product (*berge*), which is generally so impoverished as to be thrown on the waste dump.

The Salzburger percussion-table consists of a framework of 20 mm. (0.79 inch) angle and plate iron, covered by a water-tight wooden planking, 32 mm. (1.26 inches) thick, with three low wooden sides, and open at the foot. It is suspended at its corners by iron rods and chains from iron bars between four iron standards bolted to heavy pieces of timber resting on masonry. A heavy piece of timber extends along the entire length of the under side of the table; this timber is held in position by two pieces of angle iron to which it is bolted. At the upper end of this timber a U-shaped piece of iron with slotted bolt-holes is firmly secured, by means of which the length of the stroke can be regulated. This piece receives the blow from a cam-wheel keyed to a shaft. The shock (*stoss*) is imparted by the striking of the table in its retrograde movement against the block of hard wood set in an iron casting, which is bolted to a heavy timber secured in an iron framework. The intensity of the shock can be increased or diminished by means of a nut and screw at the end of a rod secured to the back of the table, which regulates the elasticity of the involute steel spring. In order to cause a regular and uniform flow of material over the table a distributing-board provided with small triangular blocks of wood is placed at the head. A wooden trough at the foot of the table receives the overflow. Motion is communicated to the cam shaft by means of a belt and pulley, and regulated by a heavy-rimmed fly-wheel. The tables are generally arranged in sets of two. A set of such tables requires the attendance of one boy, and costs complete in round numbers $1800.

The iron work in each table, including standards, etc., weighs 4040 pounds and costs $708. The tables work generally at an angle of 2° with 70 to 80 strokes of 13 to 20 mm. (0.52 to 0.79 inch) a minute, and require from 0.7 to 1.1 horse power. A single table is capable of working 800 pounds of *rösches mehl* an hour, requiring about one-half a cubic foot of water a minute; of *mittel mehl*, 400 pounds an hour, requiring 0.33 cubic foot of water a minute; of *mildes mehl*, 200 pounds an hour, requiring 0.25 cubic foot of water a minute; and of *schmund* (the very finest product) 60 to 100 pounds an hour, requiring 0.125 cubic foot of water a minute.

Working at 150 strokes of 13 mm. a minute, the cast-iron tables require 0.9 horse power. Two methods of fastening the cam-wheels (*daumlinge*) to the power shaft are used. The first necessitates the

taking of the shaft from its bearings, when the cam-wheel is slipped into place over one of its ends and keyed in position; in the second method the cam-wheel is cast in such a manner that after turning and truing it may be broken longitudinally in two pieces by a sharp blow from a hammer, and in that condition be placed on the shaft, being subsequently secured together by two rings of wrought iron, thus obviating the necessity of taking the shaft from its bearings.

The Salzburger percussion-table possesses several decided advantages over the Rittinger continuous working percussion-table, among which may be mentioned an increase in the percentage of metal, increased working surface, a diminished amount of water for the same grades of material, and less dependence upon the attention of the workman. By careful experiments it has been shown that *rösches mehl* yields 20 per cent. more silver and 30 per cent. more lead when worked on a Salzburger percussion-table than when worked on a Rittinger table. In the case of a *mittel mehl* the results were about the same, and by working a *mildes mehl* there was 30 per cent. more silver, and 20 to 30 more lead. In the case of a very *mildes mehl* (*schmund*) there was 69 per cent. more silver and 60 per cent. more lead. By reason of the parabolic curves formed by the heavier materials on the Rittinger table only two-thirds of its surface is brought into requisition, while in the Salzburger table the entire surface is covered with the material worked. The Rittinger table requires two to three times as much water as the Salzburger, and on account of the use of so great an amount of water, the particles of ore are more liable to be carried away and lost, especially in cases where the finer varieties of slime are treated. The attention of the workman is a much more important factor in the working of continuous tables than in the Salzburgers, as the curves formed by the material in the former require constant watching, and the zinc boxes at the foot must be frequently moved to correspond with their changes. This inattention at Pribram, though noticeable by day, becomes painfully apparent at night, when there is less probability of the higher officials making a sudden and unexpected appearance. From the previous comparison it would appear that although the Salzburger tables give better general results in the working of the coarser grades of material, their superiority becomes far more apparent in the working of the finer grades, such as slimes.

THE ADALBERT ORE-DRESSING HOUSE.

A part of the knockings (*grubenklein*) coming from the shaft is transported in cars, and dumped into shoots opening into the sorting-

house. The mouths of the shoots are connected by short iron gutters with ordinary fixed picking-tables, the tops of which are covered with sheet iron. The bottom of the trough is a cast-iron plate perforated with holes, 35 mm. (1.38 inches) in diameter, over which the ore is scraped by boys, and at the same time exposed to a stream of water, which serves to wash the ore and facilitate the picking. The water and stuff passing through the grate, under 35 mm. in diameter, falls into a receptacle below and is conducted through an inclined trough to the classifying revolving screens situated in the jigging-house. The larger material, over 35 mm. in diameter, is removed from the picking-table to separating tables arranged along the opposite side of the building, where it is separated by women into the following sorts: 1, *Scheideerz* (ore for hand separation); 2, *pocherz* (ore for stamping); 3, *quetscherz* (ore for crushing); 4, *berge* (waste). The *scheideerz* is further separated into a first and second grade of galena, the first consisting of pure galena, and the second containing a small portion of zinc blende, both of which are sent to the smelting works; zinc blende, which is sold; and ore for stamping (*pochgänge*), which goes to the stamping house. The *quetscherz* is removed to the rolls situated at one end of the jigging-house, while the *berge* is thrown on the waste dump.

The ore to be crushed (*quetscherz*) coming from the sorting-house is tipped into a hopper, and thence delivered to the coarse crushing rolls in the jigging-house. The crushed ore falls through a sheet-iron channel into a rotating conical sieve, of 12, 8, and 6 mm. (0.47, 0.32, and 0.24 inch) mesh, where it is separated into four sizes; the finest portion, that under 6 mm. in diameter, is transported to a reciprocating sieve (*stossrätter*) of 1 mm. (0.04 inch) mesh, like the one already described. The second and third portions are removed to the rolls in the lower crushing-house. The largest size material, passing away from the revolving screen above 12 mm. in diameter, is delivered to the middle rolls, from which it passes into a rotating sieve, which also has meshes of three sizes, 8 mm., 6 mm., and 4 mm. (0.32, 0.24, and 0.16 inch). The finest product goes to the reciprocating sieve, the second and third are concentrated on adjoining jigging machines, and the coarsest is conveyed to a set of fine rolls. These rolls are likewise provided with a revolving screen, giving however only three sizes. The finest, as in the two previous cases, goes to the reciprocating sieve, the middle product is jigged with corresponding grades from the middle rolls, while the coarsest product is removed to the rolls in the lower crushing-house. The recipro-

cating sieve having a mesh of 1 mm. separates the material into two sizes; the finer, which falls through the sieve and is consequently under 1 mm. in diameter, is removed to the smelting works, while the coarser, over 1 mm. in diameter, is sent to the lower crushing-house. The jigging of the second and third products of the middle and fine rolls takes place in a three-sieved 3 mm. (0.12 inch) mesh fine corn jigging machine of the usual construction, which yields three products, a *schlicht*, rich in galena, which is delivered to the smelting works; a second and third product, more or less enriched, which is sent to the lower crushing-house; and ore for stamping, which passes off the sieve.

The other portion of the knockings (*grubenklein*) coming from the shaft is dumped into a shoot, from which it is conveyed by a self-feeding apparatus into a large conical-shaped revolving washing trommel (*ablautertrommel*), into which water is admitted by a pipe from above. The self-feeding apparatus is similar in its construction to those before mentioned. This *ablautertrommel*, situated about 2.5 meters (8.2 feet) above the floor, supported by a solid wooden frame, and communicating with three rotating conical sieves arranged in a descending series, is 3 meters (9.84 feet) long, 1.369 meters (4.49 feet) in diameter at the smaller end, and 1.817 meters (5.96 feet) at the larger. It is constructed of timber 52 mm. (2.05 inches) thick, strengthened by heavy wrought-iron bands, and lined on the inside with sheet iron. The larger end is provided with sheet-iron buckets on the inside for the purpose of raising the ore and water from the bottom to the top of the *ablautertrommel*, so that it can fall into a sheet-iron spout connecting with the first of the series of revolving sieves. Near the ends of the *ablautertrommel* two friction rings are secured, which work in grooved friction wheels, one pair of which has motion communicated to it by means of a cog gearing. The trommel makes 10 to 12 revolutions a minute, and requires 3.296 horse power.

The rotating conical sieves just mentioned are double sieves, 1.264 meters (4.15 feet) long, 0.8 meter (2.62 feet) in diameter at the smaller end, and 1 meter (3.28 feet) at the larger. These sieves work in a heavy inclined plate-iron frame at a distance of about 4 feet apart. The power is communicated by means of a shaft extending along one side of the frame, provided with three spur wheels geared to the axes of the revolving screens. They make 30 revolutions a minute, and require together 2.658 horse power. From the first revolving screen two sizes of material are won; the larger, 42 mm. (1.65 inches) in diameter, passing from the inside screen, goes through a

trough, assisted in its progress by rapid shocks from a cam-wheel, to a rotating picking-table, similar in construction to the one in the Anna ore dressing-house, with a diameter of 4.43 meters (14.43 feet), and requiring three minutes for a revolution. The material from the picking-table is divided into two sorts, that containing ore, which is transported in cars to the separating-house directly opposite, and the sterile material, which is loaded into cars and taken to the waste dumps.

The 28 mm. (1.1 inches) size coming from the screen is carried by hand to a coarse two-sieved jigging machine with a 4 mm. (0.16 inch) sieve, 1.26 meters (4.13 feet) long, 0.65 meter (24.59 inches) wide, working at 140 strokes of 0.065 meter (2.46 inches) a minute, and requiring 2.437 horse power. From the second screen two products are won; the larger, 16 mm. (0.63 inch) in diameter, and the smaller, 12 mm. (0.47 inch), being worked separately on jigging machines of 3 mm. (0.12 inch) screen, furnishing two grades of material, poor and rich, the latter being sent to the rolls, while the former is thrown on the dump. From the third and last revolving screen two products of 6 and 4 mm. (0.24 and 0.16 inch) respectively are obtained. The 6 mm. size is worked on a *Stauch* jigging machine, which is continuous working, two-sieved, and is shown in Fig. 10, Plate IV.

This machine, intended for material from 4 to 20 mm. (0.16 to 0.79 inch), makes 140 strokes of 31.4 mm. (1.24 inches) a minute, and requires 2.9 horse power. The sieve is divided into two parts by a vertical wooden partition, A, 10.5 cm. (4.13 inches) high, is fastened to a frame of small angle iron, and is supported by a wooden frame, which, fitting closely into the box, tends to prevent the water from splashing up at the sides. The sieve frame is provided with heavy sheet-iron sides, and is suspended by two connecting rods, B, having an up-and-down motion given them by an eccentric, which can be so regulated as to give a stroke from 0 to 52.5 mm. (2.07 inches). The discharge of the heavy particles settling on the sieve is through a tube, C, 52.5 mm. in diameter, the aperture of which is closed by a puppet valve and is opened at intervals, allowing the ore to run into a larger iron pipe, D, and thence into the receivers, E. The upper portion of the smaller discharge-tube is surrounded by a low sheet-iron cylinder covered by a sieve of 1 mm. (0.04 inch) mesh, which, by being raised or lowered, regulates the discharge of material. That portion of the material which falls through the larger sieve collects in boxes of a triangular section, and is drawn off into receivers by means of stopcocks, F, at the bottom. At the

lower end of the jig frame is a curved piece of sheet iron, G, the object of which is to facilitate the passage of the waste material.

The transport screws for the *berge* and water are the same as those described in the middle-corn jigging machines. The water which is lifted by the propeller-pump passes into a wooden trough and falls on the second sieve. The automatic feed, H, of the material to be jigged is similar to that of the middle-corn jigging machines. The amount of water required for the *Stauch* jigging machine is less than that of the middle-corn jigging machine, inasmuch as a loss of water can only take place at the removal of the concentrated products through the different pipes and stopcocks. In the strict sense of the word, this is not a *continuous* working jigging machine, inasmuch as the discharge of ore takes place only when a sufficient amount has collected on the sieve, when it becomes necessary to stop the machine. The discharge of the *berge*, however, is continuous.

By this operation two products are won, ore for stamping and ore for jigging. The ore for jigging goes to a neighboring jigging machine, from which, besides the waste, three products are obtained, all of which are generally rich enough to be sent directly to the smelting works. The 4 mm. (0.16 inch) stuff goes to a jigging machine with 1.5 mm. (0.06 inch) mesh, giving a waste and two products, which are also taken to the smelting works. The material under 4 mm., together with the water, is conducted through a gutter to a concentrating-house directly opposite and at a somewhat lower level.

The material falling *through* the trough previously mentioned (under 35 mm.) passes to the jigging-house, and enters a revolving screen 1 meter (3.28 feet) long, 1.158 meters (3.8 feet) in diameter, making 25 to 30 revolutions a minute, and requiring 1.75 horse power. This screen is between two others situated at right angles to it, one of which is 3.161 meters (10.37 feet) long and 1 meter in diameter, and the other 2.845 meters (9.33 feet) long and the same in diameter.

In the upper revolving screen, which is provided with a sheet-iron trough, the material is separated into two grades. That which passes off the screen of 9 mm. (0.35 inch) mesh is conducted to the revolving screen on the right-hand side, and there divided into four sizes; the largest, between 22 and 34 mm. (0.87 and 1.34 inches), passing off this screen, is removed to a separating-table giving two grades, sterile and rich. The latter is further separated into galena, which is sent to the smelting works, and ore for stamping, which goes to the stamp-house. The sterile stuff goes directly to the waste dump.

The material passing through the 22 mm. mesh is worked on a igging machine, giving four grades of material: 1st. Ore to be farther separated by hand (*klaubwerk*), which gives the same divisions as were obtained in the separation of the larger sizes of material; 2d. galena, which is sent direct to the smelting works; 3d. a more or less enriched galena (*bleierz*) which, after a sufficient amount has been collected, is rejigged on the same machine in conjunction with the raw product from the revolving screen; 4th. ore for stamping.

The material coming through the 16 mm. (0.63 inch) mesh is worked on a middle jigging machine, giving galena for the smelting works and ore for stamping. The 12 mm. (0.47 inch) size is worked on a middle jigging machine, resulting in similar products for the smelting works and stamping-house to the one just mentioned.

The material going through the 9 mm. mesh of the upper revolving screen is conducted to the revolving screen on the left-hand side, and there divided into four sizes, 2, 4, and 6 mm. (0.08, 0.16, and 0.24 inch), and the material passing away from the screen between 6 mm. and 9 mm.

These products are all concentrated on fine jigging machines, giving as a result galena, which is sent to the smelting works; a more or less enriched product, which is rejigged, giving ore for stamping; and the material passing off the jigs (*berge*), which is taken to the waste dumps. The slimes from these revolving screens are led in channels to the slime concentrating-house and there worked. The processes conducted in the Adalbert ore-dressing house are shown in "tree" form on Plate V.

THE ADALBERT SLIME CONCENTRATING-HOUSE.

The slimes resulting from the various concentrations in the jigging-house are conducted through an inclined trough to a double spitzkasten, situated in the slime concentrating-house. The material coming from the first section of the spitzkasten flows into a receiver, from which the settlings are shovelled from time to time and concentrated on coarse three-sieved jigging machines. That portion of the material coming from the second section of the spitzkasten is also conducted into a receiver, the settlings from which are concentrated in fine three-sieved jigs. The slimes flowing away from these two receivers are conducted into a series of canals 42 feet long and 2 feet wide, the settlings of which are concentrated on continuous working Rittinger percussion-tables; while the portion flowing away from the canals is conducted to a settling tank 65 feet by 45 feet, divided into six parts.

The concentration on the Rittinger percussion-tables results in the winning of a galena *schlicht* which is sent to the smelting works, a middle product, and waste. The middle product is reconcentrated on Rittinger percussion-tables giving products fit for the smelting works. The first product from the coarse jigging machine is galena, and is sent to the smelting works, as is also the first product from the fine jigging machine. The middle products from both machines are reconcentrated on the same machines until rich enough for the smelting works.

The material passing off the coarse jig passes through a revolving screen of 1 mm. (0.04 inch) mesh similar in construction to the one at the Anna stamp-mill. The material passing off the screen is waste and is thrown on the dump, while that passing through the screen is further concentrated on percussion-tables.

THE MAGNETIC SEPARATING MACHINE.

Two of these machines are in use at Pribram (Fig. 11, Plate IV), both at the Lill ore-dressing works, where they are used for the separation of iron ore from zinc blende. These are separated from other material by the ordinary concentration processes, and are then in the form of a powder, the grains being less than 1 mm. (0.04 inch) in diameter. This powder is composed of spathic iron ore and zinc blende, and is roasted in a small oven, with frequent stirring, for an hour, when the iron ore is rendered sufficiently magnetic. It is then placed in the hopper of the machine, which is shaken by a *daumling*, or cam, A, keyed to an iron shaft, and moved by belting and pulleys. The ore falls from the mouth of this hopper into a hollow cylinder of wood with open ends, around the circumference of which horseshoe magnets, B, are set into the wood, so that their poles project about 10 mm. (0.39 inch) into the inside of the drum, or wooden cylinder. Outside the drum, and 40 cm. (15.75 inches) apart, pieces of hard wood, C, are nailed. They are triangular in section, and, by the revolution of the drum, raise a stiff and elastic wooden spring, D, 1 meter (3.28 feet) long, 6 cm. (2.36 inches) wide, and 3 cm. (1.18 inches) thick at the base, coming to an edge at the apex.

When the triangular cam releases the wooden spring, the latter strikes the drum a sharp, quick blow, sufficient to knock off any particles of zinc blende that may have attached themselves to the magnets, or the inside periphery of the drum, and partially jarring off the particles of iron ore that are attached to the magnets in the portion of the drum that is uppermost, and close to the elastic stick, but not

the more strongly magnetic pieces of ore. The iron ore that reaches the upper portion of the drum and is then jarred off falls on a sheet-iron shoot, N, and the strongly magnetic particles are now swept off the magnets into the sheet iron by means of a revolving brush, E, aided by the jarring of the wooden spring, and run through the shoot into a receptacle, F. The brush is provided with stiff bristles, and has two motions, one a revolution on its axis, given by a screw and pinion, G, and the other a back-and-forward motion, produced by a crank, H, operated by a pulley and belting on the other side of the drum. Within the axle of the brush, which consists of a piece of gaspipe, is a ball and socket joint, I, which permits this double motion. The large wooden cylinder has a narrow iron band running around its edge on both sides, which fits into four small grooved wheels, J, on which the drum rests; two of these wheels are connected by a shaft, and the other two are disconnected from the first two and from each other. Motion is communicated to the first-mentioned grooved wheels by a belt-pulley, R, on the same shaft, while the latter two merely support the drum and turn with it. A small pulley on the same shaft as the connected grooved wheels gives motion by means of a cord belting to a horizontal pulley, L, at the base of the upright shaft, M, on which the screw, G, is cut, which turns the pinion keyed to the axle of the brush. On the other side of the drum is a pulley which turns the shaft on which the cam (*daumling*), belonging to the hopper, is placed, and communicates motion by means of a belt and small pulleys to another shaft, which near the middle is bent into a crank, and gives the backward-and-forward motion to the revolving brush. In one machine small horseshoe magnets, to the number of 511, are used. These are the ordinary-sized magnets which are sold as toys in the philosophical instrument shops, and are 8 cm. (3.15 inches) long, 1.5 cm. (0.59 inch) wide, and made of 3 mm. (0.12 inch) plate. The other machine has 150 very large horseshoe magnets, 20 cm. (7.87 inches) long, 3 cm. (1.18 inches) wide, and made of 6 mm. (0.24 inch) plate; in addition there are 104 small ones. The feed is quite slow, and, to obtain the best work, the machines must not make more than five revolutions a minute. Each machine separates four cubic feet of iron ore from the zinc blende in a day of 12 hours. They have been thirteen months in use, and are very well liked, the preference being given to the one working with small magnets, as the large ones make the machine very heavy, so that it does not run smoothly. The separated zinc blende falls to the bottom of the drum, and, by the slow revolutions,

gradually works towards the sides, where it falls into troughs prepared for its reception. The first operation is to separate the original powder into an iron ore containing some blende, and a blende containing some iron. These are each reworked separately, and the division is then considered complete.

THE SMELTING WORKS.

The ore is transported in wagons from the ore-dressing establishments to the smelting works, which are situated about two miles in a northerly direction from the mines, at a cost of 80 cents a ton. The buildings are conveniently situated with respect to one another, along the base of a hill, thus facilitating the handling of material. The galena in a granular form (*graupen, gries*) is taken to the delivery-house, while the powdered material (*schlicht, mehl*) is sent direct to the weighing-house. The delivery-house contains a series of bins for the reception of the various grades of material, and a dry stamp-mill of 15 ordinary stamps, run by a water-wheel, for the purpose of pulverizing a portion of the granular material. The stamped material is thrown by hand into an inclined sieve of 1.5 mm. (0.06 inch) mesh; the coarse portions passing off the sieve are re-fed to the stamps, while that passing through the sieve is sent to the weighing-house. The other portion of the granular material is transported in cars to the upper floor of the adjoining crushing-house, situated at a lower level. The plant of this crushing-house consists of a set of 12 stamps, run by water power, similar to the ones above mentioned, 4 Koller mills, run by a steam-engine of 30 horse power, and a small oven, used for drying the ore before crushing.

These Koller mills consist of two heavy cast-iron wheels or rollers 0.31 meter (12.2 inches) wide, with cast-steel tires 0.065 meter (2.56 inches) thick, and 2.25 meters (7.38 feet) in diameter, weighing 1400 pounds. These rollers revolve around a common centre in grooves cut in the plates on which they rest, having also a motion about their own axles. The axle of the wheels is secured in a heavy cast-iron muff, fitting on the end of the power shaft, and is free to move in a vertical direction. The wheels are situated at unequal distances from the centre in order to produce a larger crushing surface.

An iron bar, keyed to the vertical shaft, at right angles to the axis of the wheels, is provided with five scrapers for the more equal distribution of the material, and one situated at the extremity of the bar for its removal. The material for crushing passes through a shoot from the floor above into a sheet-iron hopper fixed on the top of the muff and provided with two discharge pipes. The bed-plate

is of cast iron, 35 mm. (1.38 inches) in thickness, and is firmly bolted to a foundation of brick masonry. Power is communicated from below by means of heavy spur gearing. The steel tires last, on an average, one year. The wheels make from 12 to 15 revolutions a minute, and are capable of crushing 12,000 pounds of ore in 24 hours, requiring 6 to 7 horse power, at a cost of 43 cents a ton for rich ore. The crushed material passing off is conducted by an endless screw into a rotating sieve of 1.5 mm. (0.06 inch) mesh, fixed on the lower axis of a bucket elevator; the stuff passing through is removed to the weighing-house, and the coarser material, passing away from the sieve, is lifted by the elevator to the hopper, on the floor above, to be re-fed to the rolls. All the crushed products are removed by rail to the weighing-house. Adjoining the crushing-house is a small shed, containing a stone crusher similar in construction to the ordinary Blake crusher, for the purpose of crushing the limestone used both as a flux in the furnaces, and as a constituent in the preparation of the hearths of the refining ovens. The limestone is obtained from a quarry not owned by the smelting works, which is situated at a distance of five miles from them.

Next in order comes the weighing-house. This building, 218 feet long, and 54 feet wide, is built of stone, in two stories, the upper of which is on the same level with the crushing-house. The upper floor, which is supported by a series of flat stone arches, contains 36 ore bins arranged along its two sides. It also contains a room in which there is a small furnace for the determination of the moisture in the ore (*nässprobe*). The bins on one side of the building are intended for the reception of the products that have been crushed at the smelting works, and are provided with an elevated railroad track for convenience in dumping. Since the *sehlich* and *mehl* are generally delivered in a moist condition, the bins for their reception, on the other side of the building, are slightly inclined towards the front, with a gutter running along their length for drainage. A trap-door, about two feet square, is situated in front of each bin, for the purpose of dumping the weighed ore into corresponding bins on the floor below, from which it is transported in cars to the mixing-house.

In order to facilitate the weighing, a travelling crane extends along the middle of the building. This crane consists of two bars of U iron, 5 inches high, 0.25 inch thick, and 6 inches apart, bolted to cast-iron carriers, 10 feet apart, which serve as rails for the four wheels of the overhead car. The wheels are 6 inches in diameter, and their axles turn in a triangular wrought-iron frame, 26 inches

long and 18 inches high. The two frames are joined together *at the bottom* by a wrought-iron bolt, supporting a hook to which the scales are attached. The weighing-box of these scales is conveniently arranged for the handling of the ore. It consists of a stout sheet-iron box, with inclined sides, 36 inches long and 24 inches wide above, 21 inches long and 15 inches wide below, and 12 inches deep, containing 3.9 cubic feet. This box is suspended from the balance-beam by four hooks, and is provided with a hinged bottom, the doors of which open outwards. These doors are held in position by four chains, passing over a grooved wheel fixed to a shaft crossing the box. The shaft is provided at its extremity with a crank and ratchet wheel, by means of which the doors may be closed or opened. The box holds about 400 pounds of ore. The weighing takes place only on certain days in the week, and is done by contract, the weigher receiving five-eighths of a cent a ton. The mixing-house, 215 feet long by 52 feet wide, is situated on the same level as the ground floor of the weighing-house. The ore is spread out in layers, 100 feet long, 20 feet wide, and a few inches thick, and is alternately rich and poor. This operation is continued until the pile reaches a height of from four to five feet; then, beginning at one end, a section is taken from this pile by the workmen, removed to another part of the building and thoroughly mixed with shovels. In the case of an incomplete mixing, the mixer is obliged to transport the material, in his own time, back to the original pile, where he again spreads it out in layers.

From the mixing-house the material is transported in light iron hand-carts to the building containing the roasting furnaces. This building, 225 feet long by 80 feet wide, is situated at a somewhat lower level than the mixing-house, and contains eight roasting furnaces (*fortschaufelungsöfen*), at equal distances apart, and arranged parallel to the width of the building. These furnaces are 60 feet long, 12 feet wide, and are provided with eight doors on each side, seven of which are working doors, through which the ore is moved forward towards the fire by means of long shovels, and the eighth is used for firing. These doors are equidistant on each side, but are not situated opposite to each other. The fire-bridge is kept cool by a stream of water passing through it. The charges for roasting, consisting of 2000 pounds of ore, are, before their introduction into the furnace, dried in large cast-iron boxes, from which they pass through a hopper to the hearth of the furnace.

The charge is allowed to remain in front of each working door six hours; it then passes along to the next working door in the direc-

tion of the fireplace, where it remains another six hours. This operation is continued every six hours until the charge reaches the last working door, thus requiring 42 hours for the roasting of a charge. The roasted charge is drawn as a pasty mass from the furnace, through a slide-door situated in the hearth in front of the last working door, into a cart made of boiler-plate.

Each furnace requires the attendance of four men, two roasters and two helpers, who work in shifts of 12 hours each, and receive respectively 65 cents and 50 cents a shift. Besides this amount, a first, second, and third premium of 12, 8, and 4 cents is paid a shift, according to the amount of sulphur remaining in the roasted product. The first premium is paid when the amount of sulphur present is less than one per cent., and, in case the amount exceeds two per cent., no premium is paid, and the ore must be re-roasted. The products of combustion pass from the hearth of the furnace through a canal extending along its top (*flugstaubkammer*) 80 feet long, connecting with a chimney 110 feet high. An adjoining building contains a reserve of six furnaces.

The charging-house, situated at a distance of 60 feet from the roasting-house, is 200 feet long and 50 feet wide, and is divided into two parts, the first of which is used for the breaking up of the roasted mass, and the second for the mixing of the roasted mass with other products, such as rich slags, old hearths from the refining furnaces, litharges, and other products rich in silver, for charging in the shaft furnaces. The mixture for charging is variable, the following components constituting an example of its composition:

40,000	pounds	roasted ore.
16,000	"	rich slags.
1,200	"	spathic iron ore.
2,000	"	feldspar.
600	"	litharge from refining.
3,400	"	rich litharge from refining.
800	"	rich hearth scrap.
1,600	"	calcite.
1,400	"	litharge.
1,600	"	clay iron stone.
400	"	hearth scrap.
2,000	"	old hearth.
2,300	"	*kies abrände* from iron works.
2,400	"	limestone.
600	"	lead slags.
600	"	*abstrich* from cupellation.

The charge is transported in cars to an elevator adjoining the

furnace-house, by which they are lifted to the top of the furnace. These cars are cylindrical in shape, made of sheet metal, 0,823 meter (2.7 feet) in diameter, 0.724 meter (2.38 feet) high, and hold 800 pounds of the ore mixture; they dump from the bottom. From 1863 to 1869 blast furnaces of the Rittinger pattern with two tuyeres were in use. In the latter year the present style of cylindrical furnaces with five tuyeres was adopted. Such good results were obtained that in 1871 a larger furnace was built with seven tuyeres, which gave a much greater product with one-third less consumption of fuel. In 1873 a second furnace with five tuyeres was built, and in 1877 a third and fourth of same type.

Dimensions of the Blast Furnace.—From surface of ground to mouth 8.85 meters (29.04 feet); diameter in hearth 1.4 meters (4.59 feet); in throat 2.2 meters (7.22 feet). The outer diameter is 4.6 meters (15.09 feet); the outer lining of common red brick, 0.45 meter (17.72 inches) thick, is covered with a boiler-plate jacket, 6 mm. (0.24 inch) thick; the inside lining consists of firebrick, 0.6 meter (1.97 feet) thick, separated from the outer lining of red brick by 0.1 meter (3.94 inches) of open space. The upper portion of the furnace rests on six ribbed cast-iron plates (mantels), 0.052 meter (2.05 inches) thick, which are supported on cast-iron columns, 2.2 meters (7.22 feet) high, 0.25 meter (9.84 inches) in diameter, and 0.026 meter (1.02 inches) thick. These columns rest on iron plates supported by masonry. The firebrick lining is 0.6 meter (1.97 feet) thick in the lower, and 0.4 meter (1.31 feet) in the upper portion. The base of the furnace consists of an iron plate, 1.74 meters (5.71 feet) in diameter and 0.08 meter (3.15 inches) thick, situated 0.5 meter (1.64 feet) below the surface of the ground.

In the lower portion of the furnace frame is a fire-hearth, made of a bent iron plate 0.013 meter (0.51 inch) thick, surrounded by two iron bands, and secured by ten anchor plates. The sole of the furnace is lined with 0.63 meter (24.8 inches) of brasque, on which the lead (*werkblei*) settles. The slag flows into forms. Three rows of water-boxes, made of wrought iron, protect the region around the tuyeres from burning out. There are seven boxes in the lower row, five in the middle, and six in the upper; those of each row are bolted together. A course of firebrick is between each row.

The dust-chambers (*flugstaubkammer*) are in 4 parts, 7.8 meters (25.59 feet) long, 1 meter (3.28 feet) wide, and 1.6 meters (5.25 feet) high; they are cemented on the inside, to prevent the escape of gas, and vaulted with arches. The gases are conducted to these cham-

bers by sheet-iron pipes 0.6 meter (1.97 feet) in diameter, provided with valves, and thence to a chimney 9.5 meters (31.17 feet) high and 0.8 meter (2.62 feet) in diameter. The valves are used for preventing the exit of the gas when it is required for heating purposes; it is first purified in a washing apparatus, and then fed under the boilers. Fifty cubic meters (1766 cubic feet) of blast, under a pressure of 50 mm. (1.96 inches) of mercury, are required each minute for each furnace. The main blast-pipes are 0.63 meter (24.8 inches) in diameter; the tuyere-pipe is 0.08 meter (3.15 inches) in diameter. Forty to forty-five tons of mixed charge (*beschickung*), with five to six tons of fuel (40 per cent. charcoal and 60 per cent. coke), are required in twenty-four hours for each furnace.

The slag coming from these furnaces is much purer than that from the furnaces with two tuyeres, and contains only 0.0023 per cent. silver and 1.5 per cent. lead. The campaign lasts three months, the longest having been in 1877, lasting 158 days.

The lead (*werkblei*) is run into moulds from the blast furnaces, and then requires to have its percentage of silver raised before it is rich enough for refining in the cupelling furnace. This is done by the Marseilles modification of the old and well-known Pattinson process of crystallization. This Marseilles, or steam process, deserves to be better known than it is at present in the United States, as it combines rapidity of action in the desilverization of lead, with a very limited working force, and a comparatively small expenditure of capital. The only plant required is a steam boiler, a powerful steam-crane, capable of lifting ten tons, and the furnace itself.

The Pattinson process, as is generally known, is founded on the fact that when lead containing silver is melted, and, while being agitated, allowed to cool slightly, a crystallization begins of the purer portion of the lead, which is ladled out with perforated iron ladles, while the silver remains in alloy with the remaining liquid.

In place of agitating the bath of lead, during the crystallization, with a rod, as in the ordinary Pattinson process, or by means of cast-iron propellers, as in the Laveyssière system, recourse is had in the Marseilles process to the direct action of steam, which produces in the liquid mass an agitation resembling that of a very dense liquid in the state of ebullition.

This violent and continued agitation is, as is demonstrated by experience, very favorable to the separation of the lead and silver into the form of poor crystals and enriched liquid lead. The action of the steam is essentially mechanical, although there is also in the case

of impure lead a chemical refining action. The process requires a furnace for melting and crystallizing, a steam-crane, and a boiler. The furnace contains three large cast-iron kettles, or crucibles, situated at different levels: two upper kettles, for the melting of the lead to be desilverized, containing together nine to ten tons; and one lower kettle, containing fifteen to sixteen tons. A platform, at the level of the edge of the lower kettle, permits the skimming of the oxides and a supervision of the work. The large kettle is cast with three openings near the bottom, two of which are for the purpose of tapping the lead, and are closed when not in use by friction plates; the third is for the inlet of the steam, being provided with a valve for the purpose of preventing the lead from solidifying in the tube. The work-lead, as first melted in one of the upper kettles, is cleansed of its oxide, and allowed to run into the lower one; at this moment a little jet of steam is introduced in order to facilitate the mixture of the crystals of the preceding operation with the melted lead.

A film of water is then thrown on the surface of the lead, partially cooling it, and facilitating the formation of crystals. Steam, from a boiler at the pressure of 45 pounds, is now introduced into the melted lead through the inlet opening, and is caused to distribute itself in a uniform manner by being passed underneath a horizontal circular disk of cast iron secured to the bottom of the kettle, and a few inches above it.

The kettle is furnished above with a frame of angle iron covered with sheet-iron segments which are alternately raised by the workmen every few minutes in order to detach, with a long chisel, the lead which during the ebullition has come in contact with the upper portion of the kettle and there congealed. The outlet tubes are heated before tapping so that the lead will not cool in them. The frame of the sheet-iron cover carries a chimney which puts the kettle in communication with the condensation-chambers, into which the vapor enters carrying a portion of the oxides, which are then deposited in a pasty state.

When about two-thirds of the lead is crystallized, the melted and enriched lead is allowed to flow out into large oblong cast-iron moulds depressed to a level with the floor. The outlet tubes are furnished with iron grates or sieves for the purpose of retaining the crystals. Each lump of lead weighs about 5000 pounds, two being made at a casting, or 10,000 pounds, which is one-third of the contents of the kettle. The lumps of lead successively obtained in a

series of operations are raised by means of the steam-crane, and ranged according to their percentage of silver around the furnace. The lead higher in percentage than the original lead is accumulated until its amount allows the commencement of a new series of operations of which *its* percentage is the original point.

The tapping of the enriched lead completed, the lead that has been melted in the upper kettle during the crystallization is introduced and a new operation is begun.

When the impoverishment is sufficient to make merchant lead, *i. e.*, when the silver is so small in amount that its removal is no longer profitable, or when it is desired to remove the complementary lead which is in the state of crystals, a fire sufficient to melt the lead is made in the hearth of the furnace under the lower kettle.

The merchant lead is run into iron moulds of the ordinary form, disposed around an arc of a circle of which the outlet tube is the centre, by means of a trough movable on a pivot. All the work done between the running of the lead of the upper kettle into the lower kettle, and the casting into lumps of the enriched lead is called an *operation*, the length of which is about two hours. The tapping of the merchant lead and that of the complementary lead are considered as two operations, because the time necessary for the melting of the crystals in the lower kettle is nearly double the time necessary for a crystallization. The steam-crane is a very strongly built piece of machinery, is made of heavy boiler-plate, and is about 35 feet high. All its motions are automatic and are directed by the engineer, who stands on a platform connecting the two cylinders which revolve with the crane. One skilled workman and one helper, besides the engineer, comprise the working force required in the process. The argentiferous lead being then rich enough for refining goes to the cupelling furnaces, where the silver is extracted to the extent of about 100 pounds a day. The lead oxide (litharge) is sold.

The writer takes this opportunity of thanking the officials of both the ore-dressing and smelting works, for the uniform and continued courtesy shown to him while pursuing his investigations. The geological sketch has been partially taken from the "*Uebersicht des Silber und Bleibergbau bei Pribram*," written by Herr Fallen, in *Berg- und Hüttenmännisches Jahrbuch*, vol. xiii, and reference has been made to the *Desargentation et Raffinage du Plomb au moyen de la Vapeur d'eau, par M. Luce Rozan, fils, Annales des Mines, Septième Série*, Tome iii. The figures given in describing the ore-

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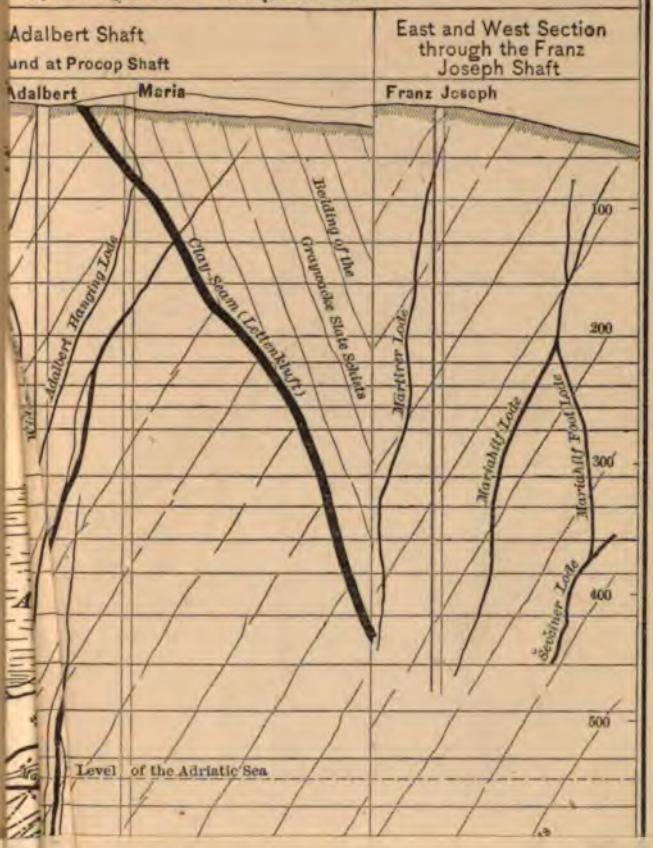
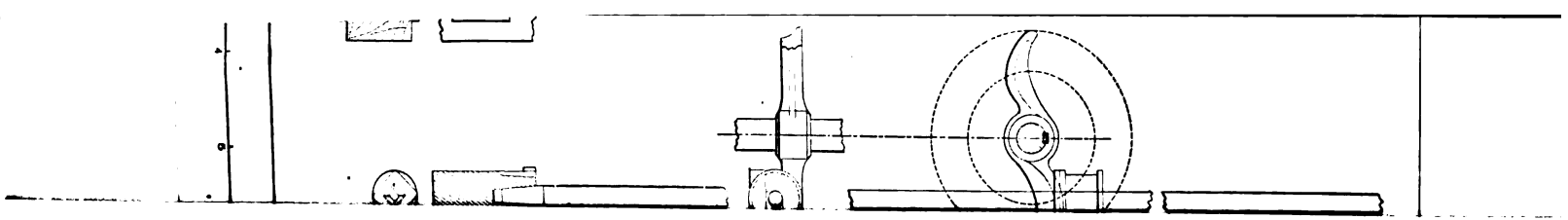
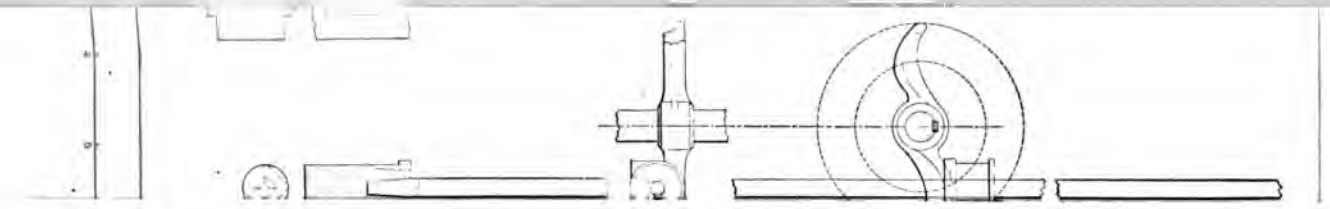
Fig. 2.

ert, Maria, & Franz Joseph Shafts.







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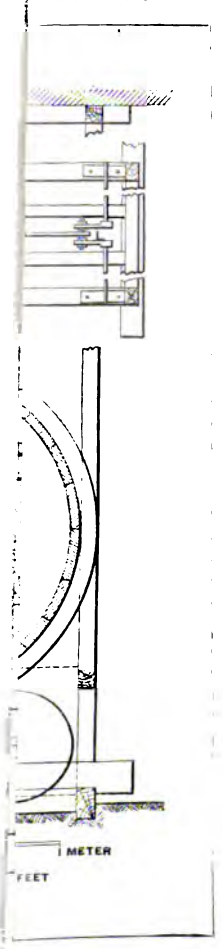
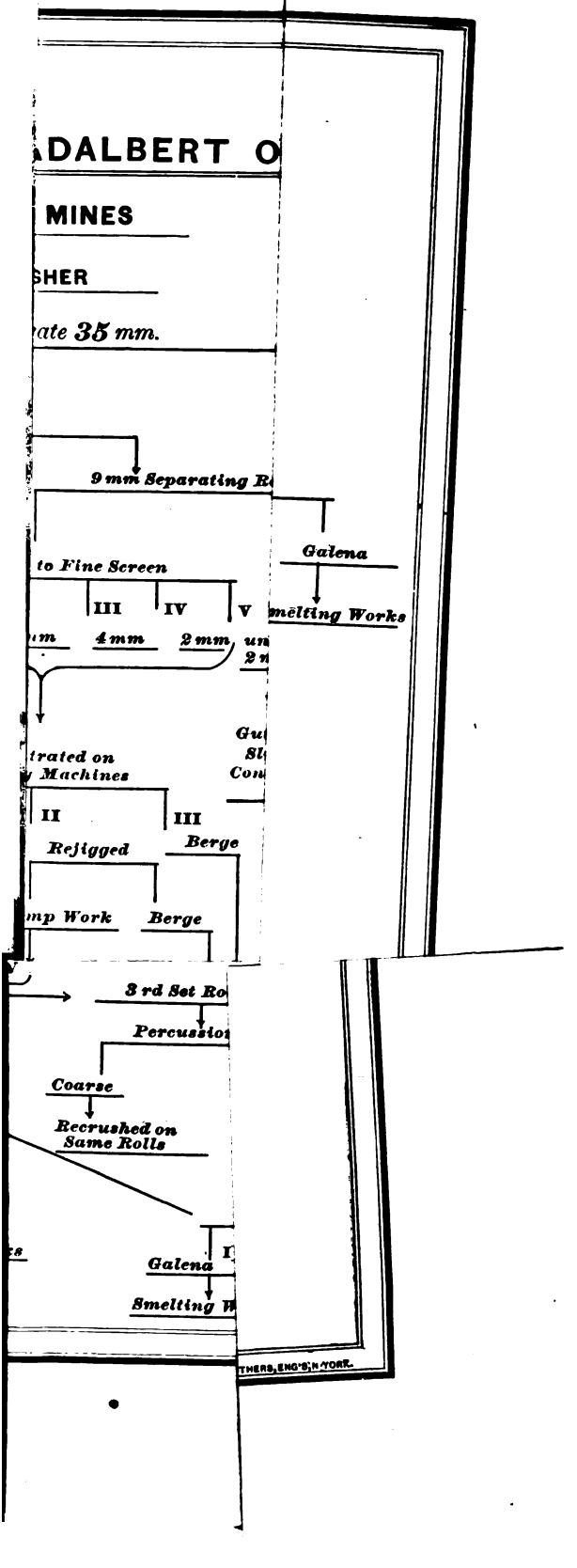


Plate V.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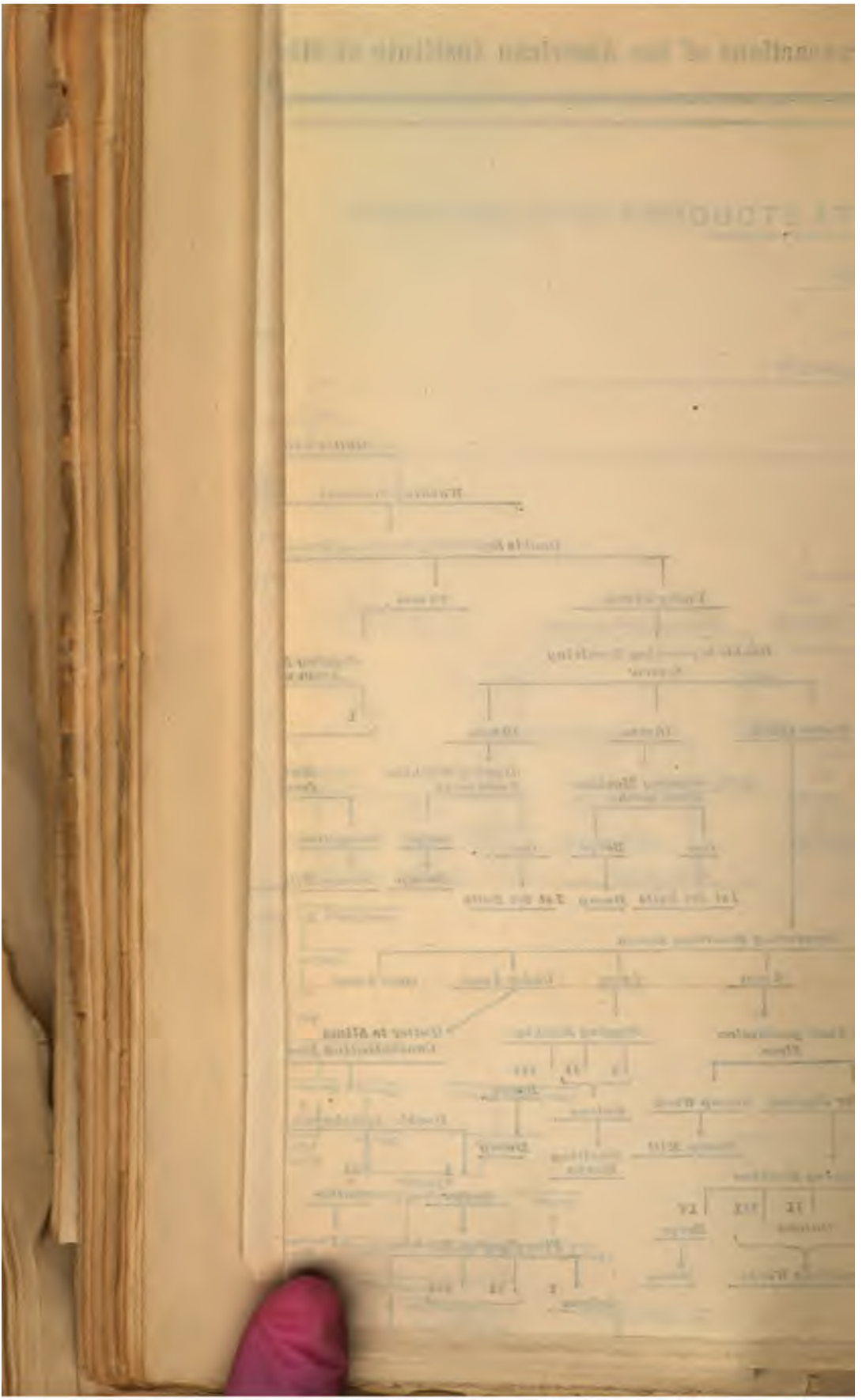


dressing works are either from actual measurement or were obtained from the under officials. The horse-powers were very accurately taken with a dynanometer for the purpose of being incorporated in a manuscript report on the works to the government, to some of the drawings of which report the writer had access.

COAL WASHING.

BY S. STUTZ, M.E., PITTSBURGH, PA.

COAL, like most other minerals, only exceptionally occurs in a sufficiently pure state to be directly available for general manufacturing purposes. And even where this is the case, the small coal or slack is usually more impure than the lump coal, as the slate, clay, etc., from the roof and bottom of the vein become mixed with it in the handling it undergoes. These impurities often exceed ten or more per cent. in addition to the impurities of the coal itself. The most common impurities of the coal are slate, or shale, clay, and sulphur. The latter occurs in different forms, but most frequently as bisulphide of iron, or iron pyrites, and as sulphate of lime, or gypsum. In both cases the impurities add greatly to the amount of ash, and where they are present in considerable quantities the raw coal, and still more the coke made from it, is unfit for the manufacture of iron. Coke will contain on an average at least fifty per cent. more ash and sulphur than the raw coal from which it is made. To the manufacturer of iron every additional per cent. of ash which his coal or coke contains is a source of additional expense, seemingly small, and yet very important in the aggregate. In the blast-furnace, for instance, the ash must be heated up to the melting-point, and, since it is composed largely of refractory substances, the consumption of carbon in melting it will be equal to at least one-half of its weight; that is, a certain part of the coke is consumed for the melting and fluxing of the ash and is lost. Besides this, it is well enough known to the iron-master that coke containing less ash makes the slag or cinder more liquid and less inclined to stick to the walls of the furnace. Fuel containing much sulphur produces generally a white iron, poor in carbon, while from the same ore and flux, with a pure fuel, a good foundry iron might be obtained.

The work of separating slate, sulphur, etc., from the coal has as yet only been successfully accomplished by the washing process. This process depends for its success on the differences in the specific

gravities of the coal and its impurities. The average specific gravities of these are:

Coal,	1.25 to 1.50
Bone coal,	1.45 to 1.80
Slate,	2.25 to 2.50
Coal or slate with pyrites,	3.20 to 3.60
Pyrites,	5.00 to 5.20

There is, however, an objectionable feature involved in the separating process, namely, that it requires the reduction or crushing of the large pieces to a comparatively small size, the fineness to which they should be reduced depending upon the intimacy of the mixture of the impurities with the coal. This crushing is a great disadvantage, if the coal is to be used in a raw state, but in no other way can the cleaning be accomplished, if the impurities are intimately combined with the coal. For the manufacture of coke, however, the crushing is not objectionable, but rather an advantage, because the smaller the pieces, the more the impurities are loosened and eliminated, if the washing is properly done, and the better and closer the coke.

Heretofore the washing process has been confined chiefly to the preparation and cleansing of bituminous coal. Latterly, however, it is coming more and more into use for the removal of slate from anthracite coal, thus superseding the old methods of hand-picking. At many of our Western mines, even where the coal is too dry for coking, it would be very profitable to wash the slack, which is now thrown away, or sold for a trifle. Washed slack coal, classified into different grades, according to size, would find an easy market, and the additional price which could be obtained for it would probably more than pay for the washing. Increasing competition will doubtless compel the washing and saving of this slack; for by such economies and processes only can every portion of the mine output be disposed of to the very best advantage. A colliery with a complete outfit of machinery, could produce, on demand, washed nut coal and slack, together with the cleanest lump coal.

There is almost no coal used for coking which may not be improved by the washing process, and which would not produce a better coke, if it was previously washed, no matter what its reputation and its nominal purity. The common expression "free from sulphur and slate" is founded on enthusiasm rather than fact. The best coal contains an appreciable, and often a considerable, percentage of injurious ingredients, which could be freed from it, to a large extent, by properly conducted washing.

Many systems and varieties of machines for coal washing have been used. To attempt a description of them all would carry me far beyond the limits set for this paper. However, I shall at the proper place speak of these systems.

Since the washing or separation of the coal from the impurities requires a previous crushing of the larger pieces to smaller ones, it will be advisable, in treating of coal washing and the plant required, to divide the subject as follows:

1st. Crushing apparatus.

2d. Separating or washing machines.

3d. General arrangement of the machinery.

1. Crushing Apparatus.

The chief object of the crushing, as already stated, is to facilitate the separation of the impurities from the coal. For most of our coals a reduction to pieces of from 0.25 to 0.375 inch in diameter is sufficient. For some inferior qualities, with a high percentage of sulphur and ash, the crushing should be carried farther, say to pieces of 0.125 to 0.1875 inch. In addition to loosening the impurities from the coal, the crushing also reduces the material to a more uniform size, and thus greatly facilitates the separation. It also improves the quality of the coke, for the smaller the coal, the more uniform and closer the coke. The machinery best adapted to the crushing of large quantities of coal is the roll-crusher, one, two, or three pairs of rolls being required, according to the character and hardness of the coal to be crushed.

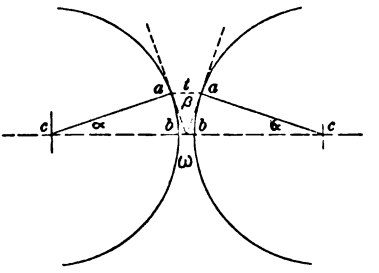
Crusher with one pair of rolls.

Plate I shows a crusher with two rolls. It is intended for the reduction of the larger pieces of slack, together with nut coal. The rolls, A, are slightly fluted and are set on strong cast-iron housings, H. The roll next the shoot, C, is provided with an arrangement to prevent the breaking of parts of the machinery. Both housings have boxes, *c*, cast with them, in which spiral springs are lodged. The latter are bent by the screw-nut, *n*, and exert their pressure upon the journal-box, *r*. The distance between the rolls, or the size of the pieces, can be easily regulated by giving more or less pressure to the springs. Motion is given to the rolls by means of the pulley, P, and is transmitted from one roll to the other by cogwheels, *w*. A flywheel, F, regulates the working of the apparatus. It is preferable to set such a crusher on the second floor of the building, above

the separator or washer, as in this case the shoot receiving the slack from the elevator may be formed of a screen the meshes of which correspond to the required size of the coal. Pieces which are already small enough will pass through the screen directly into the washer, while the larger pieces only are conducted into the rolls. The capacity of the apparatus may thus be greatly increased.

To reduce pieces of coal or other minerals of a given size to smaller ones the crushing-rolls must be sufficiently large to make the angle, α, relatively small (see Fig. 1); α being the angle between the radius,

FIG 1.



$a\ c$, drawn from the point of contact of the material to be crushed with the rolls and the centre-line, $c\ c$. This is necessary in order that the friction between the material and the rolls shall be great enough to carry the pieces between the rolls. That is:

$$P\ u \cos. \alpha > P \sin. \alpha \tan \alpha,$$
$$\text{and } u > \tan.^2 \alpha,$$

P being the force acting at the circumference of the roll, and u the coefficient of friction.

The small weight of the mineral piece is neglected.

Let the distance between the contact points, $a\ a$, of the material with the roll be t, and the size of the crushed mineral, or the width, $b\ b$, of the opening through which the fragments have to pass, be ω, then we have,

$$\frac{t-\omega}{2} = R \text{ vers. sine } \alpha,$$

and

$$R = \frac{t-\omega}{2 \text{ vers. sine } \alpha} = \frac{t-\omega}{2(1-\cos. \alpha)},$$

R being the radius of the rolls.

Thus, with the same distance, t, the angle, α, will increase as the radius of the roll decreases; and hence, to crush coarse minerals, the radius must be increased very nearly in the same ratio as t increases;

otherwise, α having become too great, the rolls will not take in the pieces.*

For ordinary conditions and with t averaging from 2.75 to 0.5 inch material, Wertheim thinks 20 degrees will be a proper value for the angle α.

For example, suppose a certain crusher is to reduce coal from 1.5 to 0.375 inch fragments, what will be the diameter of the rolls, if $\alpha = 20$ degrees?

By substituting the figures in the above formula, we have

$$R = \frac{1.5 - 0.375}{2(1 - \cos. 20°)} = 9.375 \text{ inches},$$

or, the diameter of the rolls will be 18.75 inches.

The rolls of the apparatus, represented on Plate I, are 20 inches in diameter, and are usually 4 feet in length.

According to Pernolet, the amount of material which may be crushed by a pair of rolls in a given time is equal to one-fourth or one-fifth of a band or layer, whose length is the circumference of the roll multiplied by the number of revolutions; whose width is the length of the rolls; and whose thickness is equal to the space or distance between the rolls.

Or,

$$Q = \frac{d \pi n l \omega}{4},$$

where

d = diameter of rolls,

$\pi = 3.14$,

n = number of revolutions in the given time,

l = length of rolls,

ω = space between the rolls, and

$\frac{1}{4}$ = coefficient, to allow for the irregular feeding of the material and the space between the pieces.

The crusher above described and figured in Plate I is running at the rate of 100 revolutions a minute, with a space of, say, 0.375 of an inch between the rolls.

By substituting these figures in the above formula, the amount of material crushed by the machine would be:

$$Q = \frac{20 \times 3.14 \times 100 \times 48 \times 0.375}{4} = 28{,}260 \text{ cubic inches},$$

which is equal to 16.354 cubic feet a minute, and, for a day of 10 hours, 9822 cubic feet, or over 250 tons.

* Gætzschmann, Aufbereitung, vol. i, p. 450.

My experience has been that the feeding coefficient of one-fourth is too small, and that one-third would come nearer to the result obtained in practice.

As to the power necessary to crush a certain amount of material in a given time, Wertheim has established the following expression:

$$H = \frac{Q\,(t - \omega)\,k}{T},$$

k being the coefficient of crushing strength, and T the working time.

To crush the above amount, 9822 cubic feet of slack coal, averaging, say, 0.75 inch pieces, into fragments of 0.375 inch, if $k = 200$ pounds on a square inch, would require:

$$H = \frac{9822\,(0.75 - 0.375) \times 200 \times 144}{600} = \frac{176,796}{33000} = 5.36 \text{ horse-power.}$$

In the above no allowance is made for the friction of the machinery, and it will be safe to add about 20 per cent. to the calculated amount. Thus the total horse-power would be

$$5.36 \times 1.2 = 6.4.$$

CRUSHING MACHINE WITH TWO PAIRS OF ROLLS.

Plate II represents a crushing machine with 4 rolls, one pair above the other. It is used to crush coarse screenings, with lumps from 6 to 8 inches in size. The rolls of both pairs are fluted, the upper ones coarsely, the lower ones only slightly, as in the crusher with 2 rolls. Instead of the upper fluted rolls, a pair of regular breaking rolls, with steel teeth, may be used when the coal is very hard. The housings are of cast-iron and have boxes for spring arrangements, for the lower rolls, as above. By means of hand-wheels, h, and screw-stems, s, the space between the upper rolls may be easily adjusted to suit the size of the material. The lower rolls are regulated in the same manner as before. Motion is given to the machine by means of the pulley, P, and is transmitted to the different rolls by cogwheels and idlers. A flywheel of sufficient weight, keyed upon the upper rear shaft, regulates the working. The diameter of the lower rolls is 20, and of the upper ones 18 inches, their length is uniformly 4 feet. For soft coal, the "run of the mine" can be crushed with such an apparatus. It is provided with an automatic feeding device, consisting of the movable screen, C. The latter has three sides, in the shape of a box, and is supported by four wheels, standing on rails, r. The screenbars, c, have spaces of 0.4375 inch between them, for the passage of the particles already small enough.

A jarring movement is given to the screen by means of the cam, *d*, and the spiral spring, *n*. While the cam, *d*, is causing the screen to move backwards, for the length of its stroke, the spring, *n*, is compressed and bent between the frame and the yoke, *e*; and as soon as the cam escapes, the power of the spring throws the yoke and the screen attached thereto forwards with great speed. The screen thus moving is brought to a sudden stop by the regulating screw, *o*, and the finer coal falls through, while the larger lumps are thrown forward into the rolls. As the cam is double, this is done twice each revolution. The length of the stroke, and the power necessary to the spring, *n*, can be easily adjusted, to suit the quantity to be fed at each stroke. This is done by means of the screw-nut, *o*. About 400 tons of coal may be prepared by the apparatus in a day of ten hours. To crush hard coal, like that from the Pittsburg vein, about 10 horse-power are required.

BREAKING AND CRUSHING MACHINE WITH THREE PAIRS OF ROLLS.

The engraving, Plate III, represents a breaking and crushing machine. Its object is to reduce material of different sizes, called the run of the mine, to small particles of a uniform size. It has three pairs of rolls, superposed, and set on strong cast-iron housings. The upper pair, A, is provided with sharp steel teeth, to break the large lumps into suitable pieces, while the middle and lower pairs, A^1 and A^2, are fluted in the same way as in the foregoing machines. For the crushing of ore, salt, sandstone, etc., to very small grains, the surface of the lower rolls is made smooth. The space between the rolls of each pair may be regulated to suit the material and size required. For the upper and middle pairs the adjusting is done by means of handwheels, *h*, keyed upon screw-stems, *s*, while for the lower pair, spring arrangements, lodged in boxes of the housings, form the regulating mechanism. They also serve, as before stated, to prevent accidental breaking of parts of the machinery, in case pieces of metal or unusually hard rock, mixed with the material, pass into the rolls. The machinery is set in motion by means of the belt, *b*, running over pulleys, P, P^1, P^2, and cogwheels and idlers transmit the motion from one roll to the other. A heavy flywheel, keyed upon the shaft of the rear middle roll, regulates the speed and working of the apparatus. The regular feeding of the material into the rolls is of the greatest importance, as the quantity and quality of work done depend on it. To insure this, an automatic feeding device, similar to the one described above, is adapted to each pair of rolls.

The speed of the feeding apparatus is controlled by the rate of motion of the rolls. The upper screen, C, receiving the full charge out of the bin, B, has spaces of from 3 to 4 inches between its bars, c, according to the mixture and nature of the coal. Pieces of smaller size than the meshes will pass through and fall upon the screen, C^1. The latter has meshes of 1.5 to 2 inches, which permits all smaller fragments to pass through to the lower screen, C^2. The space between the bars of the lower screen is regulated by the size required, say about 0.4375 of an inch. Particles below that size pass directly to the elevator-buckets. The material retained upon each screen is forwarded into the corresponding rolls. The rolls are 4 feet long, and are respectively 20, 18, and 16 inches in diameter. With a uniform and continuous feeding, the capacity of the machine may be estimated at about 450 tons for a day of ten hours, requiring from 12 to 15 horse-power for its working.

Both the 4- and 6-roll apparatus are in use at the Colorado Coal and Iron Company's plant, at El Moro, Colorado,* for the reduction of the run of the mine, previous to its manufacture into coke.

2. Separating or Washing Machines.

The operation of separating foreign matters or impurities from ore, coal, etc., is called respectively ore or coal washing, while the term *separating* would be more appropriate. The principle upon which the action of all coal washing appliances is based depends on the difference between the density of the coal itself and that of the accompanying foreign matters. In all of them the separation is effected either by a fall through water, or by the action of an upward current of water carrying the material with it. Great difficulties are met with in applying this principle, since the material to be treated is often very uneven as to quality, and composed of pieces of different shapes and sizes. Neither by preliminary screening, since each class of the riddled material always includes sizes smaller than the mesh of the riddle through which it has passed, nor by crushing the material to small pieces, can these difficulties be entirely overcome. It will thus be seen that the problem of coal washing is an extremely complicated one. The importance and complication of the subject may explain why so many efforts have been made during the last twenty years to arrive at an efficient solution, and why so great a number of contrivances have been designed and put to work. Coal washing is an operation which does not admit of any definite rules,

* A vertical section of the building and arrangement is shown in Plate X.

capable of general application. It is always subjected to variations, depending upon the coal-mines themselves, the locality in which they are situated, and the commercial conditions affecting them. For this reason it cannot be expected that the same arrangement of machinery can prove perfectly satisfactory in all cases.

According to Rittinger,* who so fully investigated the mechanical dressing of ores, spherical pieces, or grains of any substance, having different diameters and different densities, if allowed to fall through still water, severally acquire, in an exceedingly short space of time, a limiting velocity of descent, which thenceforth continues uniform for each separate piece. This limiting velocity, in meters a second is represented by the formula

$$5.11 \sqrt{D\,(d-1)},$$

where D is the diameter, in meters, of the piece under consideration, and d its density (the density of water being taken as unity). For irregularly shaped pieces, reduced to an average diameter, the coefficient 5.11 in the above formula changes as follows:

For rounded fragments, ...	3.20
" flattened "	2.35
" elongated "	2.65

If, for a more practical application of the formula, in place of the average diameter, as above, an assumed diameter of the pieces, measured by the diameter of the holes in the riddle through which they have passed, is substituted, the coefficients then become:

For rounded pieces, ...	2.73
" flattened "	1.92
" elongated "	2.37

Rittinger, assuming further that the material to be dealt with in coal washing ordinarily contains fragments in the proportion of one flattened and one elongated to two rounded, deduced from his calculations and experiments the following ultimate empirical formula:

$$2.44 \sqrt{D\,(d-1)} = \text{velocity in meters a second,}$$

D being the diameter in meters of the holes in the riddle; or,

$$1.28 \sqrt{D\,(d-1)} = \text{velocity in feet a second,}$$

D being the diameter of the holes in the riddle, expressed in inches.

* Lehrbuch der Aufbereitungskunde.

These formulas give the mean uniform velocity of irregular-shaped pieces of any substance, particularly coal, when falling through still water, and not affected by any disturbing influence.

The following table, calculated from the above formulas, shows the limiting velocities of the different substances composing the material to be washed. It affords a guide for the arrangement of the riddles for classifying dry coal for future separation. The average densities of pure coal, and the impurities associated with it, are taken as given in the table:

Material in pieces of different shapes.	Density.		LIMITING VELOCITY OF FALL IN METERS A SECOND.							
			Diameter of holes in the riddle.							
	d.	(d—1).	40 mm. 1½"	30 mm. 1⅛"	20 mm. ¾"	13 mm. ½"	10 mm. ⅜"	7 mm. ¼"	5 mm. 3/16"	4 mm. 5/32"
Coal.	1.3	0.3	0.267	0.231	0.189	0.152	0.134	0.112	0.095	0.084
Bone coal.....	1.6	0.6	0.378	0.327	0.267	0.215	0.189	0.158	0.133	0.119
Slate	2.2	1.2	0.535	0.463	0.378	0.304	0.267	0.223	0.188	0.168
Coal or slate with pyrites.	3.2	2.2	0.722	0.627	0.510	0.412	0.350	0.324	0.254	0.229
Pyrites.....	5.0	4.0	0.976	0.844	0.691	0.556	0.488	0.407	0.344	0.307

If a mixture of coal, slate, etc., is subjected to the action of an ascending current of water, the following conditions may occur:

1. The speed of the upward current may be exactly equal to the limiting velocity of fall of the pieces of coal, or other substances, through still water, in which case the corresponding fragments will remain stationary.

2. The speed of the current may be greater than the limiting velocity, and in this case the fragments will rise with a velocity equal to the difference.

3. The speed of the current may be less than the limiting velocity of the pieces, and in such case the latter will fall with a velocity also equal to the difference.

In all cases the velocity of the upward current in the washer must be proportioned to the size of the material treated, and this velocity should neither exceed nor fall short of certain limits. A current too strong will interfere with the classification, while a velocity of stream inferior to the velocity of the larger or denser fragments of coal will be incapable of separating the latter from the surrounding pieces of slate. It is also necessary that the upward current be uniform throughout the whole of the mass of material, since differences of

velocity at particular points will produce unequal displacement of pieces, which otherwise would fall with equal velocity.

When the coal to be treated is exposed to an upward current of water, or is allowed to fall freely through still water, it is evident that the particles do not have the freedom of motion they would have if they were isolated from each other. But any interference which may be occasioned in the process by the pieces coming in contact with one another may be obviated by allowing sufficient time and space for the process to take place. It is of great advantage to have the lifting of the material by an upward current of an intermittent character, inasmuch as flattened or elongated pieces are thereby afforded repeated opportunities of changing their positions, and thus acquiring velocities more favorable to a classification according to density, than would be the case if the motion were continuous.

Considering the washers most in use in regard to their mode of action and results, we may bring them into the following classes:

1. Machines in which the water absolutely filters through the coal to be washed. This is the case in the old piston, or Harz, jigger, in its different forms, whether worked by machinery or by hand. In this kind of machines the filtering action comes fully in play. Slack of inferior and poor quality may be treated in such machines, since the accessory action, caused by the back suction, is brought to bear upon the fine particles of impurities forming the slimes. In some cases even good results may be obtained, but this class of machines are entirely impracticable for the washing of rich slack. The loss of fine coal, which passes through the meshes of the sieve into the slimes, is considerable, and makes the apparatus wasteful. Attempts have been made to obviate this objection by leaving on the sieve of the washer a permanent layer of shale or gravel. A better and more effective remedy consists in the use of a sieve of very close mesh; the lifting action of the water is thus rendered more regular, and the loss of fine coal is somewhat diminished. These improvements, however, are carried out at the expense of the driving-power required for the working of the machine.

2. Machines in which the filtration of the water through the material is either entirely or partially obviated, and in which a continuous or intermittent ascending current of water produces the separation. These washers possess the great advantage over the former class of machines that they effect a more complete separation, and that the loss of fine coal is reduced to a minimum. They also require far less driving-power for their working. Great improve-

ments have been made in the arrangements of some of these washers both in regard to the quantity of washed coal produced and to the economy of attendance. But here I may state that, at some places, the free delivery or overflow of the washed coal is the source of the greatest trouble, when the machine is pushed and made to deliver more coal than can be properly washed; the discharge at the overflow being controlled by the quantity of water let into the machine. Some machines are forced to turn out double the amount they are intended to do, and the consequence is that the coal is badly washed. A certain length of time is absolutely necessary in order to obtain a good cleaning, and the quantity of washed coal has a direct and invariable relation to the surface of the sieve of the washer.

The separators represented on Plates IV and V belong to the latter class, an intermittent ascending current of water being forced through the material. Two wooden boxes, A and B, strongly bolted together by tie-rods and flat iron bands, contain respectively the sieve, S, and the plunger, P. The water is taken into the machine by the pipe, *g*, and the current is produced by means of the plunger, P, and a differential cam, C. Its action may be easily regulated to suit the size of any substance. In the apparatus of Plate IV the yoke of the cam, C, is connected with the plunger-rod by a swivelled screw-nut, and can be raised or lowered according to the current required. This is done by the hand-wheel, *h*, while in the machine of Plate V the stroke is regulated by the thickness of the block, *a*, below the yoke, *y*. F is a spring-buffer to limit the downward stroke of the plunger, and *v v* are valves, to prevent the filtration or back-suction of the water. The object of the arrangement of the curved partition, *n*, is to direct the fresh water upwards through the sieve and the layer of the material, and to prevent its being mixed with the slimy and muddy water of the lower portion of the box, A. Coal is brought upon the sieve from the bin, J; by passing below the gate, *b*. At each fall of the plunger, P, a certain volume of fresh water is driven through the openings of the valves, *v v*, into the box, A, and a sudden rise of the water-level and the layer of material is thus produced, causing an equal volume of water to flow over the bridge, *m*, into the channel, *c*, and to carry with it an amount of pure coal. Before leaving the washer, the mixture of water and coal passes over a drying sieve, *i*, leading the coal to the elevator buckets, while the water goes through the meshes of the sieve and flows out below. By their greater density, the pieces of slate, pyrites, etc., form the layer immediately upon the sieve, S, and

being forwarded at the same time as the coal, pass through the valve, H, into the slate-chamber, N. The inlet of the slate into the valve, H can be regulated by the lever, *d*, according to its amount. From the chamber, N, the impurities are removed through the gate, *o*, which is worked by the lever, *l*, and fall into the trough, *t*, from which they are carried away by the waste water. The fine particles of slate, etc., forming the slimes, settle below the partition, *n*, and are discharged by the valve, *k*. The use of a differential cam for the working of the plunger allows the material, after each stroke, the necessary time to deposit according to its density. An eccentric or crank cannot produce the same movement. The usual size of the sieve is 3 feet by 4 feet 6 inches, or by 4 feet 9 inches; hence its surface is 13.5 or 14.25 square feet. Washers are constructed with one or more sieves. A washer with two sieves of the above dimensions can prepare from 200 to 300 tons of slack in a day of ten hours. The amount of water required varies from 12 to 25 gallons to the bushel (76 pounds) of coal, and sometimes even more, according to the percentage and nature of the impurities contained in the material. In the apparatus of Plate V the cam movement is placed below the plunger. It makes the machinery more simple and requires less height.

In Plate VI a washer for coarse material, particularly anthracite coal, is shown. Its construction is the same as that of the machine shown in Plate V, except that the opening, *v*, is not provided with valves, the filtering action of the water being made use of. Fresh water is let in at *w*; the working of the washer is the same as that before described, and needs no further explanation.

Two washers, different from the former ones in their construction and working, are represented on Plates VII and VIII. They belong to the first class and are old in principle. The details, however, have been greatly improved, and serious objections have been removed, making the apparatus profitable and economical. In the first place, the piston, P, occupies only a part of the space below the sieve, instead of the entire area as heretofore. A part of the latter, on the side towards the overflow, *m*, is reserved for the removal of the fine sediments of slate, etc., which fall through the sieve. In the old machines of this kind the greatest objection has been the clogging up of the piston by the slimes, which could not pass below it. This objection I have removed by arranging a passage, *a*, for the slimes, and by making the top of the piston concave and inclined toward the passage, *a*. Thus, at each upward movement of the

piston, P, a current is produced, in the direction shown by the arrows, carrying the fine particles with it into the lower part of the box, A. Another very important advantage has been gained by the sloped piston, namely, a greater acceleration in the forwarding of the material toward the discharge, *m*, particularly as to the impurities upon the sieve. The movement given to the piston is also different from that in former machines. By means of the rods, *r*, fixed to yokes, *y*, and the cams, C, the piston receives a quick upward movement, while its down movement is slow, to allow time for the lifted material to settle according to gravity. In the arrangement of Plate VIII, the cam-shaft, *s*, is placed below the piston. The latter receives its motion directly from the cams, C, and is kept in position by the guide, *e*. Coal being taken upon the sieve in the same manner as before, the operation of the apparatus is similar to that of the former machines. But the amount of water required for its working is very considerable, inasmuch as the discharge of the material is effected more slowly, and depends entirely on the volume of water let out at each stroke of the piston. The movement of the latter being directly below the sieve, no forwarding action is given to the water. From 25 to 35 gallons to the bushel of slack are needed to do the same work as above, and, where water is scarce, these washers are ineffective. They also require more driving-power.

3. General Arrangement of the Machinery.

The arrangement of the different machines of a coal washing plant depends in most cases on local conditions. According to the nature of the coal, whether bituminous or dry, and its future use, the machinery may have to deal with slack coal, or with slack and nut coal, or with slack, nut, and lump coal, that is, the run of the mine. If the coal is to be made into coke, crushing to small pieces is necessary and of great advantage. For dry coal, however, crushing must be limited and avoided as much as possible. Classifying according to size, previous to washing, becomes therefore necessary.

Thus, the machinery may consist of only the separator with its classifying screens, or of a crusher and separator, either with or without classifying screens. But in all these cases its arrangement should be convenient and economical, in regard to the handling of the material.

Plate IX represents a vertical section of a washing plant for slack

coal, built at the Rochester Mine, Clearfield County, Pennsylvania.

The machinery consists of a two-roll crusher, Plate I, and a separator, Plate IV, with the necessary elevators, no classifying being necessary. K is the large screen of the coal-shoot, over which the mine-cars are dumped. Lump and nut coal are sent to market, while the slack below 0.75 inch in size passes through the meshes of the screen into the bin, H, and by means of the elevator, E, is taken up and delivered upon the shoot, *c*. The latter is formed of a screen of about 0.3125 inch mesh, to let the particles already small enough pass directly into the washer. All larger pieces go to the crusher, C. By separating the fine material from the coarse, the crusher is greatly relieved and an unnecessary waste of power prevented. The separator, S, stands directly below the crusher, and has two sieves 3 feet by 4 feet 9 inches in size, or 28.5 square feet of sieve-surface. From the washer the clean coal is taken up by the elevator, F, to be stored in bins, G, while the impurities, which fall into the trough, *t*, are carried off by the waste water. A lorry, L, holding from 150 to 160 bushels, conveys the coal to the ovens. The capacity of the machinery is 250 tons for a day of ten hours. About 8 per cent. of impurities are washed out. A pump, making from 30 to 40 strokes a minute, and delivering six gallons each stroke, furnishes all the water for the washer, coke-ovens, and boiler. The cost of washing the coal is about 2.5 cents a ton. The building is set along the main track and close to the coal-shoot, in order to save all unnecessary handling. It is 37 feet long by 28 feet wide, and is 30 feet high, including 8 feet of wall above rail and below the floor. Two coal-bins, G, 14 by 12.5 feet inside and 15 feet high, holding about 70 tons each, complete the structure. Owing to the unusual height between the top of the coke-ovens and the slack-bin, H, it became necessary to raise the floor eight feet, an equal length of the elevators and a better working thereof having thus been assured.

A plant with breaking and crushing machinery for the run of the mine, is shown on Plate X. It is in operation at the Colorado Coal and Iron Company's coke works, at El Moro, Colorado. The arrangement may be easily understood from the engraving. R is the railroad track, connected with the mine, by which the coal to be used for coking is brought to the plant. Scarcity of water near the mine compelled the company to locate the coke works about four miles north of the mine. The coal is dumped into the bin, B,

and goes first through the breaking and crushing machine, C, represented on a larger scale in Plate III. The reduced material is taken up by the elevator, E, to be emptied into the hopper, J, feeding the washer, S. From the latter the clean coal is carried off by the elevator, F, and stored in bins, G, while the impurities, dropping into the trough, *t*, are swept away by the waste water. The washer is shown more fully on Plate IV. Cars, L L, holding about 45 bushels each, carry the coal to the ovens. Owing to a great amount of bony coal, the washing process has to be conducted with great care. From 15 to 20 per cent. of impurities are eliminated on an average. Before the machinery was erected the coke made from unwashed slack contained from 16 to 23 per cent. of ash, but the washing process has brought the ash down to about 10 or 11 per cent., and the quality of coke is suitable for any smelting purpose. The amount of water required may be estimated at from 20 to 25 gallons for each bushel of coal. From 200 to 250 tons of coal are washed in a day of 10 hours, at a cost of 3 or 4 cents a ton. The mode of transmitting power to the different pieces of apparatus is plainly shown by the engraving, and needs no further explanation. The main building of the plant measures 28 by 30 feet, and is 20 feet *high*. The crusher-room, between the main building and the coal-bins, covers an area of 15 by 22 feet. In front of the main building are the bins for the washed coal, 14 by 16 feet, holding about 65 tons each. The boiler-house is on the left side, looking from the washer towards the crusher, and is 12 by 30 feet.

The first set of the washing machinery to supply 100 ovens with coal was started in August, 1879, and arrangements were made, at that time, in view of an increase, for a second set of the same machinery. This was built at the beginning of last year, for the second 100 ovens. The company has now 200 ovens in operation, supplied with washed coal.

Finally, to give a complete idea of the general arrangement of a coal-washing plant, in connection with coke-works, Plate XI shows both together. They were erected last year for the Penn Gas Coal Company, Westmoreland County, Pennsylvania.

Fig. 1 is a side elevation of the ovens, seen from the rear of the washing plant; Fig. 2 is a top view; and Fig. 3 a cross-section, taken in the line, *x x*, of Fig. 2.

The Penn Gas Coal Company has four mines in the immediate neighborhood, and wanted to bring the slack from these mines together to one establishment. On this account, the building, A, of the

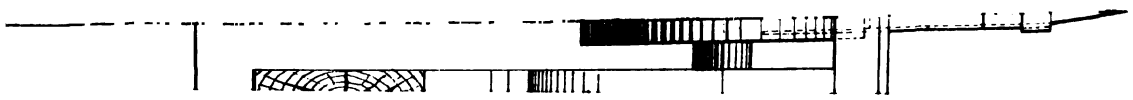
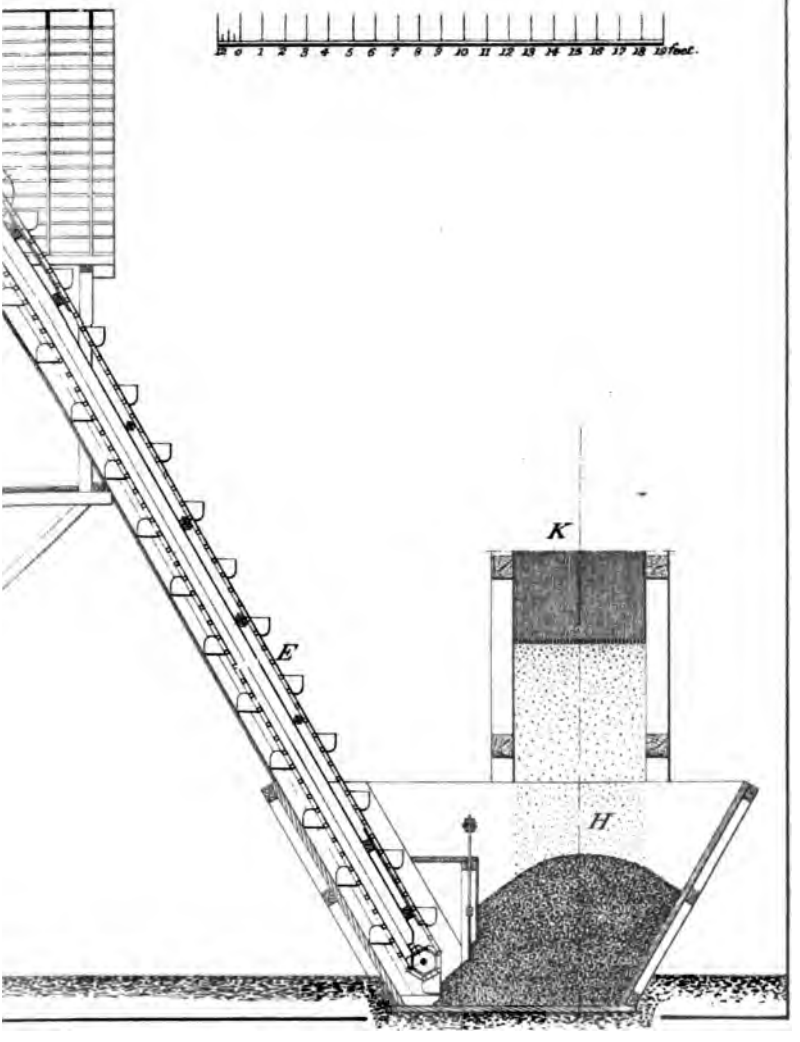
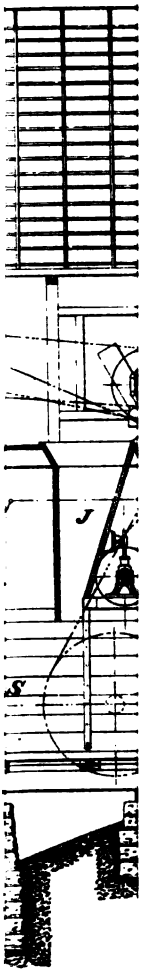


Fig.



AM. PHOTO-LITHO.CO. N.Y. (OSBORNE'S PROCESS)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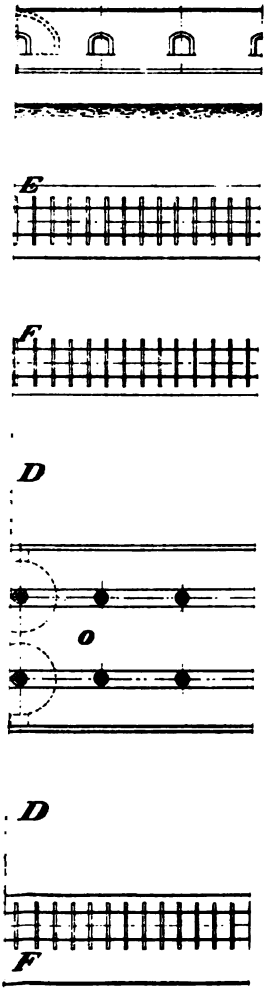

E
F
D
o
D
F

washing plant was erected about midway of the ground, at a distance of 55 feet from the centre of the main track of the railroad. The ground is very flat, and nearly on the same level as the road. For safety in case of high water, it was necessary to set the building upon a wall 8 feet in height. The capacity of the machinery is sufficient to supply 100 coke-ovens with coal, and arranged so as to provide for an increase of a second 100 ovens, if necessary. Of this number 50 ovens, O, were built last year. They are 12 feet in diameter, and 6 feet 6 inches high, set in double line. E is the slack-track over which the coal is brought to the place and dumped into the bin, B. Owing to difficulties of drainage, the bin could not be set in the ground, and the track had to be built on an embankment, as shown in Fig. 3. D, D, are yards for the drawing of the coke, and F the tracks for the coke cars, connected with the main track. From the bin, B, the slack is conveyed to and from the machinery in the same way as shown in Plate IX. The cleaned coal reaches the bins, C, and thence is taken to the ovens. The 50 ovens, O′, to complete the first 100, have not yet been built. The steam-engine is 14 by 30 inches, and has sufficient power to drive a second set of machinery, to be erected in an additional building, marked by dotted lines, Fig. 2. H is the boiler house, and T a tank to contain water for the quenching of the coke and for the washing process. The distribution of the ovens on both sides of the washing plant greatly facilitates the handling of the washed coal, the hauling being short and economical. Only few places allow such arrangement.

PITTSBURGH, February 10th, 1881.

THE CARBONIC ACID GAS PROCESS AT THE KEHLEY RUN COLLIERY FIRE.

BY H. M. CHANCE, M.D., PHILADELPHIA.

THE failure of the carbonic acid gas method at the Kehley Run Colliery has given rise to a conviction of the inefficiency of the process; but a careful survey of the facts, and of the conditions under which it was tried, will show that a fair trial of the method was not and could not be made at this colliery; its failure in this particular instance therefore, should not be held as evidence against the process. In itself, the method seems to be theoretically perfect, but in prac-

tice several conditions are essential to its successful use; if these are not satisfied, a successful result cannot be expected.

In 1871 the carbonic acid method was unsuccessfully employed by the Lehigh Coal and Navigation Company at its No. 6 colliery. Of the conditions under which this trial was made, I have no data.

In 1874 a fire at the Wynnstay Colliery, Ruabon (England), was successfully fought by carbonic acid generated by the action of chlorhydric acid upon limestone. The method is described in a paper read before the Iron and Steel Institute by Mr. George Thompson.

Other trials are recorded in the *North of England Institute Transactions* and other publications, but I have not been able to give the time necessary to the compilation of the records.

When first discovered, the Kehley Run fire was probably confined to two old breasts (Nos. 8 and 9) on the first lift. These breasts had been abandoned for many years, and little was known of their condition. Although the mammoth bed is about fifty feet thick from floor to roof, not more than from eight to twelve feet of this has been mined from these workings; there was, therefore, a large amount of coal, exclusive of that left in the pillars, still remaining in this part of the mine. The fire may have originated in the gob, of which there was probably a large quantity in each breast; but its cause is not known. An almost continous line of crop-falls marked the site of the workings, and, shortly after the fire was discovered, these were greatly enlarged by additional falls.

The gas with which it was proposed to extinguish the fire was generated by a square brick furnace, open at the top, but hermetically closed in beneath the grate-bars. A 9-inch pipe was carried into the furnace beneath the bars, to carry off the gas. Anthracite coal and charcoal were alternately used as fuel, and a small quantity of lime (5 per cent.) added from time to time. The contractors stated that the lime was used to "*prevent the generation of carbonic oxide.*" The fire was usually kept from six to twelve inches deep.

The 9-inch delivery-pipe was water-jacketed for a distance of about twenty feet, to reduce the temperature of the gas. The gas was taken from this 9-inch pipe by four 3-inch distributing-pipes, to each of which was attached a steam siphon injector, supplied with steam at sixty pounds pressure. It was claimed that these injectors would exhaust from the furnace and discharge into the mine about 1500 cubic feet of gas per minute. Spray jets were introduced into the delivery-pipes a short distance beyond the injectors, to effect

a further cooling of the gas. Three of the delivery-pipes were driven down through the crop-fall débris directly into one of the breasts, and the fourth was connected with a diamond-drill hole, opening into the lower part of the same working.

Attempts to make the crop-falls air-tight by filling them with decomposed outcrop coal dust and earth were only partially successful. The crop-falls were so large and numerous that an enormous quantity of gas constantly leaked through the material with which they had been filled, and as the ground surrounding and covering the site of the fire was constantly settling, fissures were probably produced, allowing a free escape of gas and influx of air. At no time could the mine be considered air-tight. The temperature of the gases thrown into the mine was certainly at times very high, and rarely if ever fell below 100° F. Before the spray jets were introduced, the temperature was certainly above the boiling-point of water.

It is extremely doubtful whether the furnace was producing a mixture of carbonic acid and nitrogen free from carbonic oxide; on this point there seems to be considerable diversity of opinion.

The conditions essential to the successful use of this method may be grouped under two heads: Those relating to the mine, and those governing the gas supply.

1st. The mine, or that portion on fire, must be rendered approximately air-tight; and the supply of gas must be largely in excess of the capacity of the leaks.

2d. *a*. The production of carbonic oxide by the generating furnace must be prevented.

b. The temperature of the injected gas should be moderate (70°–100° F.).

c. After combustion has ceased, sufficient time must be given to insure a thorough cooling of the mine; and during this period, the supply of gas must not be appreciably diminished.

It cannot be asserted that any one of these conditions was satisfied at the Kehley Run fire; and it does not seem just that the method should be condemned because of its failure in this particular instance.

Its advantages over other methods of dealing with mine-fires are too evident to need further comment, and to these very advantages may be attributed the disfavor into which it has fallen. They have induced engineers to use it in cases to which it is ill-adapted, namely, at mines which could not be rendered even approximately air-tight.

THE WHITWELL FIREBRICK HOT-BLAST STOVE, AND ITS RECENT IMPROVEMENTS.

BY F. W. GORDON, PITTSBURGH, PA.

THE Whitwell firebrick hot-blast stove, for furnace use, may be seen in its three main stages of development in the accompanying drawings. Fig. 1 is the stove of 1869, the year in which it was thoroughly tested at the Consett furnaces, England; Fig. 2, the stove of 1876 and 1877, in which it was intended to reduce the cost by increasing the height; Fig. 3, the stove of 1880. Many modifications were made from time to time, generally in the direction of improvement, but the drawings illustrate the main features of progress.

In the stove of 1869 the plan was to introduce the gas at A. and pass it up and down between each alternate wall, the air in the reverse direction, passing in at B. The friction in this stove was so great, owing to the restricted area of the passages and the many reversals of the gaseous current, that it was deemed imprudent to build the stoves higher than 28′ 6″. Another reason was that the great importance of cleaning was carefully kept in view, and it was very difficult to operate any hand scraper even to this depth. For these reasons the 22′ × 28½′ stove held the field for several years. A slight change made from this was to the 18′ × 40′ stove, where the height was increased, but the number of walls diminished. In this stove the friction was somewhat reduced, but so was the heating surface, and although it cost a little less it was not any better.

The next important change, seen in Fig. 2, was by increasing the height to 60 feet and keeping the full number of walls in the stove. The heating surface and mass were much increased in proportion to the cost, and the friction decreased by alternating over and under two or more walls, instead of one, as formerly. This stove gave admirable satisfaction, but, although the proper doors were provided, it was very difficult to clean, owing to the long distance the scrapers had to traverse.

Stove No. 3 is a modification of No. 2. The great question was how to decrease the cost without impairing in any way the

efficiency or durability of the stove? In this plan the gas passes up and down the stove twice, as does the blast, but in the reverse direction. Thus we have very far departed from the 1869 stove, where the ups and downs were five in number. The number of walls traversed in this case are five, while the cross or stay-walls are eleven, instead of three, as formerly. We have thus increased the area of surface very greatly, while the friction of the total stove has not been increased, since the speed of the currents has been much diminished by increasing the aggregate area of the passages.

It is a matter of much importance to have this properly proportioned, as it insures:

1st. The utilization of every foot of surface exposed.

2d. The prolonged use of the stove without cleaning.

3d. The forcible contact of the air with every heated brick, and,

4th. The thorough mixture of the gas and air while heating the stove, causing the most perfect combustion.

If the area for the passage of a limited amount of gas or air were indefinitely increased the surface exposed would be but partly utilized. We consider that an area so great that the currents are much below ten miles an hour too great to be wholly effective. This current, ordinarily called a "fresh breeze," will prevent the deposit of the light flocculent material on the walls, so highly detrimental to the heating power of the stove. Only heavy solid matter will collect, which must be scraped off. To this end we provide a swivel crane, pivoted in the centre of the stove top. The carriage of this crane can be made to operate the chain directly over any of the heating passages. To this chain is attached a heavy weighted scraper, counterbalanced on the other end of the crane beams. The scraper can be rapidly run up and down the walls even while quite hot. In fact the stove can be taken off blast, and the work of cleaning immediately commenced. The chimney damper being left slightly open, all heat will be drawn away from the men at work.

The speed of gas consequent on thus limiting the area of the passages does not present any difficulty in the matter of draft. A chimney with a head of draft equal to 1 inch of water is all that is necessary, and 150′ to 175′ in height is ample. The entire friction of the stove, when on gas for normal duty, does not exceed ¼ inch of water; indeed the friction of the blast, from one end to the other, is only ⅛ of an inch, the valve friction not being taken into consideration.

You will observe that, though slightly modified, the air-channels for heating the oxidizing air are in the main the same as in the older

stove. The bricks being fully heated, the air in passing through the channels takes up an amount of heat which very materially aids the combustion. We might here say, that as blast-furnace gas is necessarily much reduced in combustibility, by an admixture of from 14 to 15 per cent. of CO_2, it is desirable to use all means to effect a thorough combustion. These channels in the wall may be objected to as ineffective after the first few moments, but the work of any continuous regenerative furnace will fully demonstrate that a very great amount of heat can be taken up by air having a brick partition between it and the flame. We always insure a sufficient strength in the walls after the passages are deducted, and these openings are not, therefore, detrimental to the strength of the stove. Another means lately introduced to aid the combustion of the gas is to introduce a jet of heated air from the stove then on blast, admitting this blast through a number of small tuyeres, placed in the bottom of the combustion-chamber. This we have found amazingly effective.

In the "ideal working" of the blast furnace, where all the carbon is burned at the tuyeres to CO, and all reduction is effected by the oxygen of the ore burning this gas to CO_2, 5.7 pounds of air will be required for each pound of carbon charged. In this case (were it possible) a good grade of ore could be smelted with .506 pound of carbon to the pound of iron, actual reduction requiring by the above assumed process .312 pound of carbon, and $.312 \times 8080 = 2521$ calories. The portion of this heat at the tuyeres is $.312 \times 2473 = 771.57$ calories (C to CO), and $.312 \times 5607 = 1749.38$ in zone of reduction (the CO to CO_2). The total calories required, independent of the heat from the blast, being about 3000, there is further required in the zone of combustion, 479 calories, which require .194 pound carbon, burned to CO. This latter passes away in that condition. The total carbon, therefore, consumed from the fuel is $.312 + .194 = .506$ pound, which multiplied by 5.7 pounds gives 2.884 pounds of air to the pound of iron. This measure of economy need not be expected to be reached until our present mode of reduction can be entirely changed. It is however the smallest amount of air possible for a 50 per cent. ore, using 25 per cent. of lime. By the aid of the Whitwell hotblast this same quality of ore has been through a year's work reduced with .819 pounds of carbon to the pound of iron, which required 3.75 pounds of air; the proportion of CO to CO_2 being much smaller than in the case assumed. Where, however, an ordinary economy of product with high heats is attained, say 1 pound of carbon (1.15 pounds of coke), to the pound of iron, the weight of

air would scarcely exceed 4.5 pounds. For practice, however, in figuring the heating surface of the stoves, we assume 5½ pounds of air to the pound of iron, and as the air at ordinary atmospheric temperatures weighs .076 pounds per cubic foot, 72 cubic feet of air are required to make 1 pound of iron; or, allowing 23 hours' blowing for a day's work, 117 cubic feet of air per minute are required for 1 ton of iron per day. From actual tests we know that 5 square feet of surface in the plant of stoves is sufficient for 1 cubic foot of air per minute, but allowing 20 per cent. loss in engines, etc. (a fair allowance where machinery is good), 4 feet of surface may be provided in the stoves to 1 of air per minute, counting piston displacement. The surface, therefore, required when good ores are to be smelted, will be $117 \times 5 = 585$ square feet per ton of iron per day.

We must here call attention to a matter of some importance, with regard to the Whitwell stoves. If the stoves are to be placed at an old furnace, an increased output may be assumed of 70 to 100 per cent. The only instances in which this has not been the case is where stoves of insufficient capacity have been put up. Where ordinary cast-iron pipe stoves have made a product with certain ores and fuel, and it is proposed to erect a furnace with Whitwell stoves, they must be built with a view to this increased output. Thus we expect for a 15-foot coke furnace 100 tons of iron per day, or if the ores are especially good a make of 115 tons can be reached, and where the ores are lean and silicious 75 tons is all that can be expected. We wish to have it well borne in mind that the leaner the ore the more air per ton is required, and *vice versa*, and it would be approximately correct to calculate the size of the stoves based upon the amount of ore used. Or the following method may be used, which avoids the extremes of basing the size of the stoves upon the air per minute with the assumption of a fixed quantity per pound, and the percentages of the ores. Multiply the number of pounds of ore required per pound of iron by 190, and add the constant 220. This will equal the total stove heating surface per ton of iron per 24 hours. This, again, depends upon the cubical contents of the blast furnace, since, ordinarily, the leaner the ores the less the product; and as the leaner ores require the greater amount of air per unit of iron, therefore the greater amount of heating surface is required. The American coke practice with high heats has reached the production of 1 ton of iron per 24 hours to 90 cubic feet of furnace contents with 60 per cent. ores. Then, as above, $190 \times 1\frac{2}{3}$ tons of ore to ton of iron $= 317 + 220 = 537$,

which divided by 90 = 6, nearly. We use 6.5 as a multiplier; that is, we multiply the cubical contents of the furnace by 6½ to obtain the heating surface of the stoves, and this result will be nearly correct for any character of ore. For small furnaces this had better be somewhat increased, and for larger ones it may be slightly decreased, since small furnaces are greater producers per unit of contents. We have thus a "rule of thumb" for calculating the stove surface required.

Let us here call attention to a bad practice of comparing furnaces by the height and the diameter of the bosh. With these two measurements the cubic capacity may be twice as great in one case as the other. We have calculated 16-foot and 13-foot furnaces, and found them practically alike. The cubical capacity comprises all the dimensions, and is a much more reasonable basis of comparison than any single measurement. A comparison of duty should be made by stating how many cubic feet are required to make a ton of iron in twenty-four hours.

In this connection we should explain how so many furnaces have been supplied with altogether too little stove power. The English furnaces had an average output of one ton of iron per twenty-four hours per 250 feet of cubic capacity, the range being from 170 to 430. Mr. Whitwell, during his lifetime, had control of this county's business, and he did not or would not recognize the economic consideration of large output having greater importance here as compared with the English practice. His recommendations, therefore, based upon furnace size, were always too small for high heats in American practice. Few of the old-type stoves, with their limited heating surface, had anything like enough power to do the work expected of them. Thus the stoves were said to do little better than the cast iron, as far as make and output were concerned; but none who had them ever regretted putting them in, since the economy of maintenance alone was full recompense for the outlay. Many stove plants have now been in use for years, and have not cost a dollar since their erection, and not one of them has cost anything of any moment.

It is often asked, can a furnace afford gas enough to supply these stoves and give a heat of 1400° F. to the blast in addition to raising the necessary steam? As this is a vital question I will endeavor to answer it satisfactorily. It is no use to save the fuel in the furnace, if what is saved must be expended outside, except perhaps a cheaper grade might be used under the boilers. Practice has proved that

any well-appointed furnace, even with good economy of fuel, produces gas in sufficient quantity and of good enough quality to raise all steam required and heat the blast in cast-iron pipes to 900° F. For a unit of blast we will assume that the same amount of steam is required when either high heats or ordinary heats are used, and we will, therefore, only compare the amount of gas necessary to raise the blast temperature in the one case to 900°, and in the other to 1400° F. The gas from a blast furnace working economically may be taken to be

$CO_2 = 17.25$ per cent.
$CO = 25.25$ "
$N = 57.50$ "

The temperature produced by the combustion of this gas is that due to the further oxidation of the CO less the heat absorbed by the CO_2 and N and air introduced for the combustion.

Weight of gas to be burned, say, ...	100.
Add air required to burn the 25.25 CO to CO_2 . . .	62.6
Add for air of dilution, ...	40.4
	203.0

The temperature, therefore (specific heat, being .24), is

$$\frac{10.82 \times 5600}{203 \times .24} = 1248° \text{ C} = 2270° \text{ F.}$$

This disregards the initial temperature of the gas and air. This 203 is twice the weight of the gas consumed, and as the blast and gas are in the proportion of 1 to 1.35 nearly, the amount of heat produced by the combustion of all the gases would be equal to all the blast heated to a temperature $1.35 \times 2 \times 2270°$ F. $= 6129°$ F. If, therefore, all the heat of the gases could be imparted to the air only $\frac{900}{6129} = 14.7$ per cent. would be required to heat it to 900°. But to generate 900° F. in a cast-iron stove with the ordinary degree of rapidity the escaping gases must go off at 1200°, that is only 1070° of the 2270° can be made available, requiring 31.1 per cent. of the gases burned in the ovens instead of 14.7 per cent. The heat lost by radiation from the walls of the ordinary cast-iron ovens is very great, raising the total combustion to nearly 50 per cent. of the gas.

This same reasoning applied to the Whitwell stoves shows that $\frac{1400}{6129} = 22.8°$ of all the heat of the consumed gases is returned to the furnaces, and as the escaping temperature is only 400°, 2270° — 400 = 1870° F. are available for heating the blast, and 2270

$\times$ 22.8 $\div$ 1870 = 28 per cent. To this, as before, must be added the heat lost by radiation from the stoves, which, with their heavy walls and the recurring cooling action of the blast, never attains a temperature of more than 150° on the average. In fact, the naked hand can be held on the casing in many places. It is, therefore, fair to assume that the loss by radiation cannot be anything like what it is in the ordinary pipe stove, and 35 per cent. of the gas will suffice to raise the blast to 1400° F., which is about the amount obtained by measuring the gas currents. In any view, however, it is clear that less gas is required to raise the temperature in a Whitwell stove to 1400° F. than to 900° in the best style of a cast-iron pipe stove.

The above 35 per cent. of the gas will weigh in units of blast 35 per cent. $\times$ 1.35 = .4725, and multiplied by 2 = .945 gives the weight of the products of combustion, and as this amount is used in two stoves at a time, this quantity (.4725) passes through each.

The 21′ $\times$ 60′ stove has a heating surface of 29,000 square feet, and three of these will have 87,000 square feet, which divided by 6.5 gives 13,538 cubic feet of furnace capacity. But as in large furnaces this may be increased, as above stated, our estimate is for a furnace of 15,000 cubic feet capacity, or for a product with rich ores of 150 tons of iron per day, equal to 100 cubic feet of furnace capacity to the ton of iron. According to our figures 150 $\times$ 117 = 17,550 cubic feet of air per minute, and that multiplied by 5 = 87,750 square feet of surface in the stoves, which nearly tallies with the former estimate. Somewhat less air than the above is required for this amount of iron when economy of fuel is made the prime object.

The proportion of the several passages through which the gas and air passes in these stoves has been a matter of much study. We will call attention to these currents which serve so well to keep the walls clear of fine light dirt. In the first passage of the blast the aggregate is 20.8 square feet, and the surface of the openings is 114 feet linear. As the friction is proportional to the surface and the square of the velocity, we multiply by these factors to get a unit of resistance, so that the entire resistance shall be the least possible, and the mass the greatest possible. Volume of air = 17,750 feet per minute, divided by 20.8 = 853 velocity per minute, or 14.2′ per second. $14.2^2 \times 114 = 22{,}988$ units of resistance (neglecting the compression of the air). In the second passage the resistance is 20,310, and in the third 18,934, since they are made freer to compensate for the expansion of the air by the heat taken up. The last passage or com-

bustion-chamber has an area of 35.5 square feet with only 52 feet of surface linear, measured around its walls, this chamber being especially designed for the combustion of the gases. It is evident from these data that the flow of the gas being but one-half the quantity of the air, the up and down movements, subdividing the large heating chamber into three parts, cannot be any detriment in causing too much friction to the currents; and when we find less than ¼ inch of water as the actual friction in practice, we feel safe in claiming the following important advantages derived from this subdivision.

1. The complete contact of the air and the brick surface.
2. The burning gas comes in contact with every brick exposed.
3. The light flocculent material is carried on by the current, and is not deposited on the brick walls, to prevent them from absorbing the heat.

These stoves have been greatly simplified in construction, being built almost entirely of 9-inch ordinary-sized brick. The shapes seen on the drawing (Fig. 3) are very simple and easily made, and the number needed of each, marked on it, shows how few are required. Further, the double passage that we have just referred to enables us to use a common, cheap grade of firebrick in the up and down passages next the chimney valve, as the first flush of heat is taken up in the combustion-chamber and the first down passage. This effects a very considerable saving in the construction of these stoves. The arches below are a thorough network of brick and firebrick only, and are so short in their span that it is impossible for them to fall in. The base of the centre wall is greatly increased in width to compensate for the bricks removed to form the arches across it. These arches are numerous and small, and induce a thorough spreading of the gas and blast.

As before mentioned, the product of the furnace is much increased by the application of the superheated air, and to show that such is a natural sequence we would refer to I. Lowthian Bell's report of the Consett furnaces when the Whitwell stoves maintained a constant temperature in the blast of 1324° F.* The furnaces were almost identical; the material the same—ore, fuel, and limestone; but one was blown with air at 850° F. and the other with air at 1324° F. The furnace with the air at 850° F. required 22.75 cwts. of coke to make a ton of iron, while the one with air heated to 1324° F. made the iron with 18 cwts., a saving of 4.75 cwts. to the ton, or

* Chemical Phenomena of Iron Smelting, page 161.

21.3 per cent., attributable to nothing save the heat of the blast. The product was really the same both in quantity and quality, but the furnace with 850° air required 5.07 pounds of air to the pound of iron, while the other required only 3.75 pounds. The fact of the make being the same is easily explained, when it is known that the same blowing power was used for both furnaces. The resistance to highly heated air in passing in at the tuyeres being much greater than that of the moderately heated, less would therefore enter the same tuyere area. Both these furnaces had a tuyere area of 80 square inches, and Weisbach's formula for resistance would show that as 5 pounds entered the one set of tuyeres at a temperature of 850°, only 3.77 pounds of air would enter the other, all other things being equal, which they must have been, since these proportions are almost exactly the same as the air received by the furnaces. Had the blowing power been independent and the same amount of air been injected into each furnace in a given time, the relative production would undoubtedly have been 5 for the furnace with superheated air to 3.75, for the other, the make rising from 60 tons per day to 80.

This brings us to what may seem to some at first sight rather difficult to believe, namely: the construction of a furnace plant with Whitwell stoves, royalty, and all, costs no more money than when a fair plant of cast pipe stoves is put in. A blast furnace for given materials is large or small according to the product, and to say it is an 80-ton furnace, a 60-ton, etc., is more to the point than to give any of the dimensions. The diameter of bosh, cubic contents, size of engines or boilers, are only the details of the whole, whose duty is some uncertain quantity of pig metal. Taking these English data (and far better results can be shown than these), if the same engines, boilers, buildings, and furnace proper can be made to produce 80 instead of 60 tons per day, without being any more tasked, they are unquestionably worth 33⅓ per cent. more money. We will assume, therefore, for comparison, these parts of a certain furnace to produce a stated quantity of iron to cost $100,000, and with the cast-iron stoves to cost $120,000. The Whitwell stove plant with chimney and flues will not cost over $50,000, or a total of $150,000. But as this latter for actual output is worth one-third more than the former, its relative value would be $120{,}000 + \frac{120000}{3} = \$160{,}000$. Or, to take it the other way: If the machinery, etc., all regulated by amount of air required, could be reduced in the ratio of from 5 to 3.75, and

with the aid of the stoves still make the same amount of iron, and this saving added to the cost of a cast pipe stove plant, there would be more than enough money to build a fine plant of Whitwells.

The above is by no means our best results. The application of the stoves to existing plants has fully doubled the output in several instances. Why is this great increase of output the result of the application of the Whitwells? By blowing superheated air into the furnace a combination of several advantageous points results. Less fuel is used per ton, therefore there is more ore in the furnace. Less blast is used, therefore less heat is carried away in the gases. The sensible heat of the gases is always lower, and part of this loss is prevented. The more highly heated the blast the greater affinity its oxygen will have for the incandescent carbon in the hearth, therefore the more rapid the formation of the CO; and the more rapid the combustion the more the area of combustion is confined, and the sooner the zone of reduction will be established. The more intense the combustion the more limited the zone of fusion, the intensity of the heat being greater but the quantity of heat less. The work performed where high heats are employed is done quickly and well, but the heat is very rapidly reduced to such a point that reduction can actively commence and be perfected in a region much lower down in the furnace. Thus a low furnace will do the same work as a much higher one, and a high one can be proportionately pushed, so that in either case a great economy of fuel results.

The variation in the temperature of the blast from the stove, from the time it is first put on till taken off, an hour afterwards, is objected to by some furnacemen. This change is very small with good-sized stoves; still we have devised a means of providing against any change. The device by which this is effected is based upon the difference in the resistance to the passage of a certain quantity of air at different temperatures. A freely moving piston forms a valve, the upper end of which is pressed upon directly by the cold air, and the lower end by the heated column which has passed through the stoves, valves, and part of the pipes. If the air is much heated, the pressure in this latter pipe is so much less by the extra resistance due to that temperature, and the result is a depression of the valve by the cold air column, and an admission of cold air to regulate the temperature of the blast entering the furnace. When the temperature in the stove diminishes the balance of these pressures causes the valve to rise and reduce proportionally the amount of cold air. By weighting the lever attached to the valve a constant temperature can be

maintained at the tuyeres. We are endeavoring to perfect a pyrometer operated by the difference in friction of hot and cool air, and think we can succeed.

It is easy to demonstrate what an immense quantity of heat a plant of these stoves contains, and what a small proportion of this is taken away by each hour's run. The only reason there is any noticeable difference in the temperature of the blast is, that a slight film of surface is more highly heated than the body of the bricks; but, the body of the bricks being heated through and through, the heat is very slowly taken away, and the surface temperature can be well kept up for a very long time when sufficiently large stoves are in use, as herein recommended. As already stated, one stove, 21 feet diameter, and 60 feet high, has a surface of 29,000 square feet. This has 17,550 cubic feet of air passed through it per minute, or 1,053,000 per hour, the length of ordinary air-blow. The weight of this air is 1,053,000 × .076 = 80,028 pounds, which, multiplied by .237 (specific heat) × 1300° F. (less temperature of cold air pipe) = 24,654,500 pound-units per hour. As the specific heat of firebrick may be taken at .2, and the average thickness of the walls 6 inches, compared with heating surface (by averaging the 9-inch division walls and the small wall crossings), then 29,000 × .2 × 3-inch (half wall) × 10 (weight of square foot of brick 1 inch thick in pounds), we have the units of heat per degree of wall = 174,000. But the hour's blast absorbs 24,654,500 units, requiring a lowering of the temperature of 140° F. of the mass of the walls under consideration. This does not, however, represent the diminution of the blast temperature, as the greater reduction of temperature in the walls is toward the cold end, leaving the heat of the hot end well up to the maximum. This reduction, however, is the great safeguard to the longevity of the stove. If the gas were admitted continuously, burning among the heated walls, the temperature would go on increasing, as long as a balance could be maintained in its favor against radiation and heat of the escaping gases, and the destruction of the walls would inevitably result. But in each three hours one hour is taken up in carrying away the heat given to this stove during the other two, and as a consequence the walls never attain a temperature that can injure them. Our stoves, therefore, are everlasting. This heat, imparted from the walls of the stove and given up to the blast, has to traverse through the bricks, an average distance of 1½ inches, since the wall is 6 inches thick, and acted upon both sides. If, as is supposed by some, the walls are only heated and cooled half

an inch, we would ask, where does the heat come from to heat the volume of blast, as ordinarily proportioned to the stoves? Since the quantity of heat conducted through solid bodies is inversely proportional to the distance travelled, and directly proportional to the difference in temperature, and as one inch of firebrick has speed of conduction per minute of .33 units to the square foot to each degree of Fahrenheit, for 1½ inches thick, the amount will be .22 units; and since the number of units per minute per square foot of surface is 410,910 ÷ 29,000 = 14.2, we have 14.2 ÷ .22 = 65° as the difference between the heat at the surface and the heat at the centre of the walls. If the walls were made thinner than 6 inches, the difference in temperature would be less; but the total heat of the wall would be relatively decreased; and as the above difference is very slight, compared with the entire heat of the mass, this mass should not be decreased or sacrificed to heating surface.

Mr. Whitwell held there was no economy in decreasing the walls below 9 inches, claiming that the surface was sufficient to absorb all the heat these walls could spare for regular work; but we consider that the heating surface cannot be too great if the mass is not sacrificed in getting it. We have adopted the thickness of 4½ inches for the thin walls, and 9 inches for the dividing walls, as bricks lay more cheaply in this shape, and because it is the best, or nearly the best, proportion between surface and mass.

It would, of course, be an easy matter to construct these stoves with 2-inch walls, and thus, with less brick mass, and the same iron shell and valves, obtain perhaps 70 per cent. more heating surface. But, from the foregoing considerations, mass seems preferable to surface. At least the latter should not be increased at the expense of the mass. We think there is sufficient conductivity in firebrick for an average thickness of 6 inches, heated and cooled alternately on each side, and that the surface so obtained is sufficient to abstract and utilize all the heat from the mass to its centre, and thus produce a practically uniform temperature in the blast.

An objection sometimes offered to the use of high heats is, that it injures the quality of the iron, and to answer broadly that it does not would not be accepted as conclusive. But we can, nevertheless, say, without hesitancy, that far from injuring the iron the quality of the iron is improved. The facts bear this out, but we give the following reasons why it should be so. The following materials are generally supposed to be detrimental to iron: Phosphorus, sulphur, and silicon. The first cannot be removed even in part by any

known processes in the blast furnace. The second may, by heavy liming, be carried into the slag to a great extent, if it is not volatilized in the upper part of the furnace; but it is generally recognized that high or low heat in the blast has little or nothing to do with the presence of sulphur in the pig. It has been generally supposed, however, that high temperature increases the amount of silicon in the pig. This belief grew out of the contrast of cold-blast and hot-blast charcoal iron, the former having about ½ per cent. and the latter from 2 to 2½ per cent. as ordinarily made in the old-style charcoal furnace process. But the fact is in neither case should there be more than the smaller amount of silicon in the pig with charcoal for fuel.

All the silica can be fluxed with a proper admixture of lime before its reduction can take place, except that portion which is covered and protected by the carbon of the fuel, that is to say, the silica of the ash. This ash it is which causes the trouble in all light, weak, and highly siliconized irons. When fuel high in ash is charged into the furnace do not blame the furnace manager, for he cannot make strong iron; but if the fuel ash is low, and the iron weak, an increase of the burden or lime, or both, is indicated. High temperature of the blast intensifies the heat of the hearth but only in a very slight degree, but it promotes economy of fuel to a very marked degree. It also reduces proportionally the consumption of the fuel in the hearth, since all the carbon deposition in the reducing zone will expose to the action of the flux the ash which was contained in that portion of the fuel. If all the ash of an average coke were to descend to the tuyeres, and 1½ tons of coke were used for a ton of iron, the iron might contain from 6 to 7 per cent. of silicon, but by using high heats the coke can be reduced to one ton and a large proportion of the carbon and ash separated in the preparatory action of the furnace.

DISCUSSION.

MR. BIRKINBINE: Mr. President: Do I understand the gentleman to claim that with two furnaces of equal size and proportions, similarly equipped, using the same ore, flux and fuel, and operated under the same management; in fact, alike in all respects, except that one was supplied with Whitwell stoves, while the other used good iron pipe stoves, that the one equipped with Whitwell stoves would produce 60 to 70 per cent. more pig iron than the furnace having iron pipe stoves and show corresponding reduction in fuel consumption?

MR. GORDON: That is what I intended to say, and it can be verified.

MR. BIRKINBINE: I regret that I was not aware of the purport of this paper, so that I might have come prepared with actual data for which under the circumstances I must trust to memory. But I do not feel that we should allow the statement that the use of the Whitwell stoves will augment the product of a given plant 60 to 70 per cent. to pass unchallenged. To no one person do the blast-furnace managers owe more than to the late Thomas Whitwell, for it was he who taught us the true value of a hot-blast in controlling the operations of a blast-furnace. Up to the time his stoves were presented for public consideration, our furnace managers had treated the hot-blast stoves more as an accessory to the plant than as an essential feature with which to control and operate it, but I submit that the claims made for the superiority of the Whitwell stoves have not been substantiated in American practice. In a paper presented at the Washington meeting five years ago, I claimed that, if the same amount of study and attention were devoted to the construction of iron pipe stoves as is bestowed upon the Whitwell plants, and if an equal amount of care were exercised in watching the iron pipe stoves as is demanded for the firebrick stoves, the claim for superior durability would have little foundation. You, Mr. President and many of the gentlemen now present, are well aware that it has been the too prevalent practice to allow an iron pipe stove to care for itself. An occasional inspection to see that the gas was burning, was considered sufficient, and the pipes were subject to sudden changes of temperature by throwing open the doors when the oven was considered too hot, or when the furnace was blowing out, causing the pipes to check and crack. It has not come within my experience to find many burned pipes, although I have examined a large number which have been removed from ovens. The cracks indicate that they are damaged or destroyed by sudden or extreme changes of temperature.

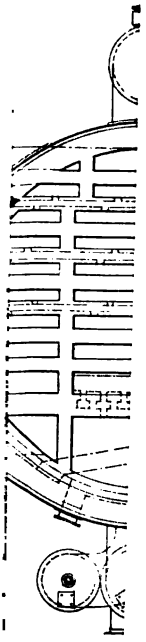
As to the durability of iron pipe stoves, permit me to cite an example or two. About two months ago I inspected an iron pipe stove which had been constructed in 1860 and had been in almost constant use, and the proprietor informed me that during these twenty years of use not a pipe or brick had been removed from this oven. I am at present rebuilding the firebrick arches of the combustion-chambers of an iron pipe stove. These arches were cut in ridges by the gases, the brick cindered, and 15 inches of this cinder had accu-

mulated on the bottom of the chambers, yet we have not discovered a single defective pipe, although they were placed just above these chambers which show the action of the intense heat so strongly. Other instances of durability could be mentioned if time would permit.

Concerning the fuel economy I cannot speak as definitely on the coke practice as on that of the anthracite furnaces, but while in Pittsburgh I found that the work done at the Eliza and Soho furnaces with iron pipe stoves compared very favorably when size of furnace, quality of stock, and product were considered, with other furnaces using the Whitwell stoves.

As to the results with anthracite furnaces I know that to-day the Cedar Point furnace at Port Henry, N. Y., 17 feet × 71 feet, notwithstanding it has 4 Whitwell stoves under efficient management, is not making as much pig iron, nor working on as low fuel consumption as the Warwick furnace, which is smaller, 15 × 55, and uses leaner ores. During our Wilkesbarre meeting in 1877 an opportunity was given to compare the contemporaneous working of the Port Henry and Scranton furnaces using the same ore and coal, and the statements which were then offered for examination showed no perceptible difference between the furnace employing superheated blast and blast at 800° from iron pipe stoves.

These facts are presented as they occur to me now in this crude manner. I would not be considered as detracting from the value of any improvement in blast-furnace construction or operation. I have no financial or personal interest in any form of hot-blast stove, and have no pet theories, but I insist that within our present knowledge, the firebrick stoves have not developed the economy of fuel claimed for them, and I very much doubt if Mr. Gordon can name any three furnaces having Whitwell stoves which use anthracite coal, or anthracite with a small mixture of coke, which can show a record either as to amount of iron produced or economy of fuel consumption, which will not compare unfavorably with the work now being done at the furnace of the Pottstown Iron Company, managed by our member, Mr. Janney; the Warwick furnace managed by our member, Mr. Cook; and the North Lebanon furnace operated by our member, Mr. Brock. The mixture of ores at the first two named furnaces run from 38 to 42 per cent., and at the latter plant all Cornwall ore is used, which is highly sulphurous, and averages less than 50 per cent.; and all three have iron pipe stoves.



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*BRAZOS COAL-FIELD, TEXAS.**

BY CHARLES A. ASHBURNER, PHILADELPHIA.

VERY little is known of the economical value of the coal-beds of the State of Texas. The first authentic statement in regard to their occurrence is that contained in the reports of the United States Explorations for the Pacific Railroad, near the 32d parallel of latitude, published in 1853–55. Professor William P. Blake reports, "that a number of seams of bituminous coal, varying in thickness from two to four feet, have been opened along the Brazos River, in Young County, about one hundred and fifty miles west of Fort Worth." Dr. Shumard also states, "that the characteristic fossil forms of the Carboniferous Era have been found with this coal, and considers the age of the formation established. Fossils obtained from the carboniferous limestone remove all doubt of the age of these deposits."†

In the spring of 1879, I was called upon by some Eastern capitalists to make an examination of the Brazos coal-field, in order to obtain the thickness, extent, and value of the coal which could be mined and be made merchantable for steam, heating, and metallurgical purposes. The demand for coal in this section of the country is great, and a fuel which in our Eastern markets might be considered of inferior quality, would here find a ready sale.

It must be remembered that the market value of a coal does not depend upon its absolute purity, but upon its actual value in heat units which it is capable of producing. A poor coal which can be cheaply mined near the consumer, is infinitely more remunerative to a mining company than a superior coal whose cost to the consumer is greatly increased by high mining charges and railroad freights. The value of the Texan coals does not depend upon their purity but upon their low first cost and nearness to a market.

A glance at a geological map of the United States, will show that the Brazos coal-field is the extreme southwestern extension of what may be called the Missourian, Fourth or Western bituminous coal

* I am permitted by the gentlemen for whom the examination was made to publish the general statements contained in this paper.

† Macfarlane's Coal Regions of America. More recently brief mention has been made of the coal-field in the pamphlets of the State geological survey. These reports are, however, too general, too indefinite, and too impracticable to permit of any conclusions as to the value of the coal as an economical, merchantable fuel.

basin. This basin spreads over the southwestern part of Iowa, Western Missouri and Eastern Kansas, eastern part of the Indian Territory, Western and Central Arkansas, and ends in Northern Texas. Professor C. H. Hitchcock in the report of the ninth census estimates the area of the basin, which is the largest in the United States, as 84,000 square miles. The area embraced within the State of Texas, according to A. R. Roessler, is 6000 square miles. Professor B. F. Shumard estimates the thickness of the measures at 300 feet.*

The official geological reports of the several States all claim that the Missourian coal-field is continuous from Iowa to Texas. My knowledge of the main features of the field is too general to add much corroborative testimony. From the dissimilarity of the coal at McAllister in Indian Territory to that found in the vicinity of Fort Belknap, Texas, many of the local geologists deny the statement that the basins in the Territory and State are connected. The principal ground upon which the objection is made, is that along the Red River carboniferous strata are not found, and that the coals in the two localities are entirely different. When it is remembered that the Red River rocks belong to a newer and overlying formation to the coal measures, there seems to be but little doubt that the coal-strata must pass considerably below the bed of the Red River and connect the otherwise severed fields. The mere fact that the Texan coals, so far as at present known, are so very much inferior to the coal which is being mined at McAllister amounts to nothing. I have examined the coal bed in the mine at McAllister and the coal bed in the drifts at Fort Belknap over 205 miles distant, and have found less difference than exists in Pennsylvania between beds of the coal-measures in localities only a few miles apart. We know nothing yet as to the relative position in the measures of the Belknap and McAllister beds, so that their great difference in quality cannot establish the fact of a break between the two basins.

The area in which my examinations were principally made lies in the northern part of Stephens County, along the Clear Fork of the Brazos River and in the southern part of Young County.

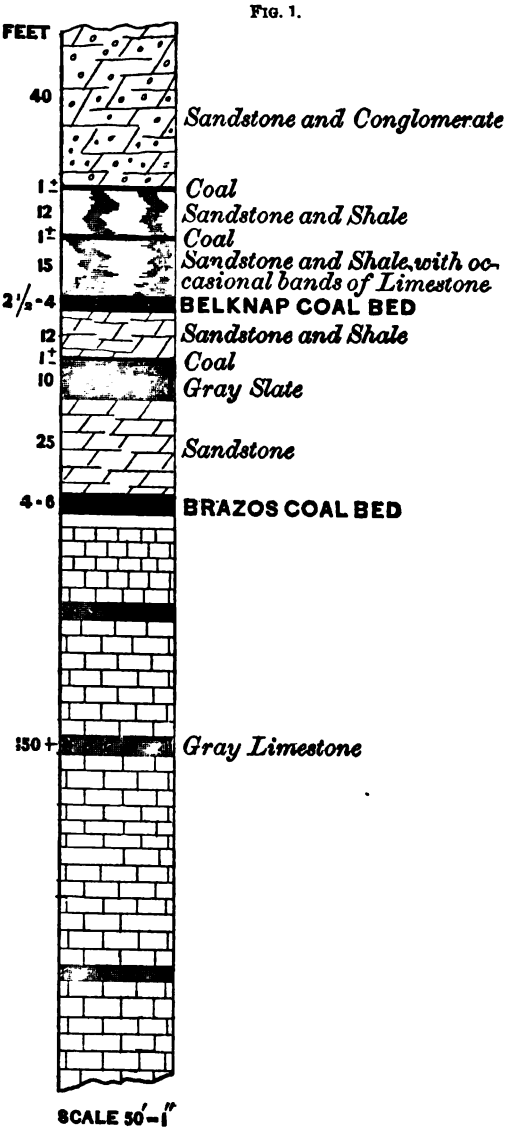
There are but two beds which may possibly prove to be commercial. The upper bed I have called the *Belknap* bed, because it has been opened for a great many years in the vicinity of old Fort Belknap, and the lower bed the *Brazos*, since as yet it has only been found in the tributary waters of the Brazos River. Besides these

* This is very much in excess of the thickness which I determined between Crystal Falls, Fort Belknap, and Graham. Professor Shumard does not state the exact position in the basin at which his measurement was made.

two beds there are a number of associated coal-seams which have never been found of workable thickness.

The vertical interval containing the coal-beds is less than 100 feet in thickness and lies between a sandstone and conglomerate and a hard gray limestone. A general section of the strata compiled from measurements made in the vicinity of Crystal Falls, Stephens County, and Fort Belknap, Young County, is as follows:

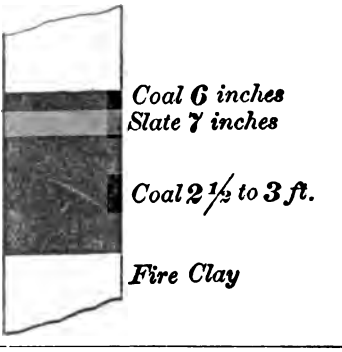
FIG. 1.



The sandstone and conglomerate at the top of the section immediately underlies most of the prairie flat between Crystal Falls and Fort Belknap. The sandstone is a comparatively soft, friable, and ferruginous stone. The conglomerate beds have no marked persistency; the rock itself bears no resemblance to the carboniferous conglomerate so familiar to geologists in the Eastern States. It is quite soft, very ferruginous, and the pebbles are small, often quite irregular in shape, and are generally formed from sandstone, which at times is very calcareous. Below this sandstone and conglomerate is a group of strata, 85 feet thick, composed of sandstones, shales, slates, fire-clays, and coal-beds, and below these coal-measures occurs a hard, gray limestone, the total thickness of which is unknown. I have measured 150 feet in the valley of the Brazos River. This succession of the strata is not unlike that to be found in many localities where the carboniferous rocks are found in the Middle States. It seems to point clearly to the conclusion that the top sandstone and conglomerate is the representative of the carboniferous conglomerate or Millstone Grit, that the limestone is the subcarboniferous or Mountain limestone, known generally throughout the Mississippi Valley as the St. Louis or Chester limestone, and that the included coal-measures are really subconglomerate.*

The upper, or Belknap coal-bed, has been most extensively prospected. It covers a large extent of territory, especially in Stephens and Young counties, as is proved further on. The bed usually consists of two benches, or layers of coal, as shown in the section.

FIG. 2.



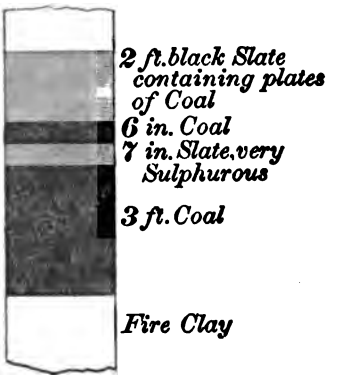
* In many places in Northwestern Pennsylvania and West Virginia sections have been constructed which compare in many respects with the Brazos section. In the former locality no Mountain limestone has been found, but coal occurs under the base of the Pottsville or carboniferous conglomerate No. XII; in the Virginias the same section exists, and in addition the Mountain (locally called Lewisburg) limestone is boldly developed.

The upper bench of coal is usually about 6 inches thick, while the lower bench varies from 2½ to 3 feet thick. The two benches are separated by 7 inches, more or less, of black slate or clay, containing a great deal of sulphur in the form of iron pyrites or sulphide of iron. The coal itself is poor, bony, and extremely sulphurous. The bed is always overlaid by a very ferruginous sandstone or conglomerate. From the unvarying character of this rock it seems quite probable that the territory underlaid by the coal-bed is coextensive with the area underlaid by the sandstone, the latter being easily recognized wherever it occurs. The bed was found to outcrop in the following localities:

1. The Belknap coal-bed may be seen about three-quarters of a mile southwest of Crystal Falls, at an elevation of 1115 feet, the barometric elevation of Widow Nash's house in Crystal Falls being assumed at 1100 feet above ocean level.*

At this point the following section is exposed:

FIG. 3.



Where this coal is seen there is only from 5 to 15 feet of cover. When a coal-bed contains a large amount of sulphur, and occurs under so little cover as at this point, little can be judged of what its actual condition and character would be when drifted on under good solid cover, which would prevent the infiltration of surface-water. About 300 feet south of this point the Belknap bed outcrops again at about the same elevation. At this latter outcrop a fire-clay bed is observed immediately under the coal. This is an invariable accompaniment of our bituminous coal-beds, and doubtless will always be found under the Belknap bed.

* The elevations given in this paper were determined by a Hicks's aneroid barometer. No opportunity was afforded of determining the elevation of Crystal Falls instrumentally.

On account of the imperfect character of the diggings the fire-clay is not always observed where the coal-bed is seen to outcrop. Below the fire-clay at this last locality occurs a hard, iron sandstone, which is immediately underlaid by an outcrop, indicating a coal-bed about 1 foot thick. This bed is about 12 feet below the bottom of the Belknap bed. A number of small coal-beds, such as this last, are seen in a number of localities either above or below the Belknap bed. I do not think they will ever prove workable.

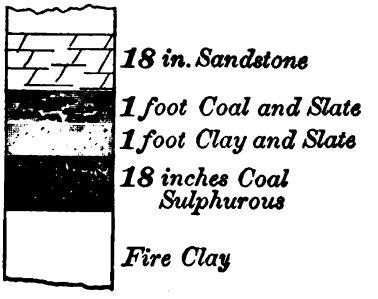
2. The next place where the Belknap bed was visited was at the O'Neill opening, about 600 feet southeast of the first outcrop mentioned. The character and thickness of the bed is the same as at the former outcrop; the elevation of the opening is 1100 feet. The coal bed has been drifted on for 200 feet, more or less, and proves no better under 15 or 20 feet of sandstone cover than on the outcrop. The bed is overlaid by a hard ferruginous sandstone. Three hundred feet northeast of the mouth of the drift there is 40 feet of cover to the coal-bed, and a quarter of a mile north of the opening the prairie flat is 1185 feet high, showing 80 feet of cover to the bed.

3. The same bed outcrops on the Walker tract to the south of Samuel Sloan's house, and about three-quarters of a mile, a little north of east of the O'Neill opening. The elevation of the bed at this point is 1105 feet, and 35 feet above the level of the Clear Fork, which flows at the foot of the hill immediately below the outcrop.

4. I found another outcrop of the same bed in the bank of the creek, about 450 feet southeast of the last mentioned. The elevation of this outcrop is 1110 feet. This last locality is about half a mile north of Crystal Falls.

5. The next outcrop visited was found on the east bank of the Clear Fork, about a quarter of a mile north of the above outcrop, and in the northwestern corner of the J. T. Pinkney tract. This is known as the Ballard opening. The following section is exposed:

FIG. 4.



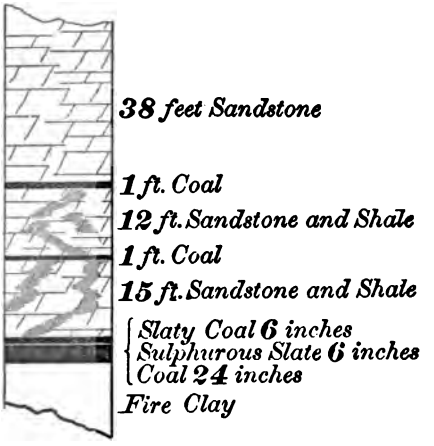
The coal is rather hard and bright, but has the unvariable character of the Belknap bed in being very slaty and very sulphurous. The elevation of the coal at this opening is 1080 feet, and about 10 feet above the Clear Fork.

6. On Coal Creek, in the southeastern corner of section 3 of the railroad lands, the Belknap bed is exposed, showing from 2½ to 3 feet of coal. The bed is here immediately overlaid by 18 inches of highly sulphurous black slate, above which occurs 15 feet of hard, shaly iron sandstone. The same bed has been found at several other points along the creek.

7. The Belknap bed outcrops around the base of Coal Mountain, 7 miles southwest of Crystal Falls, and between Hubbard and Gonzales creeks. The elevation of the coal is 1135 feet, and of the top of the mountain 1200 feet.

The following section is observed:

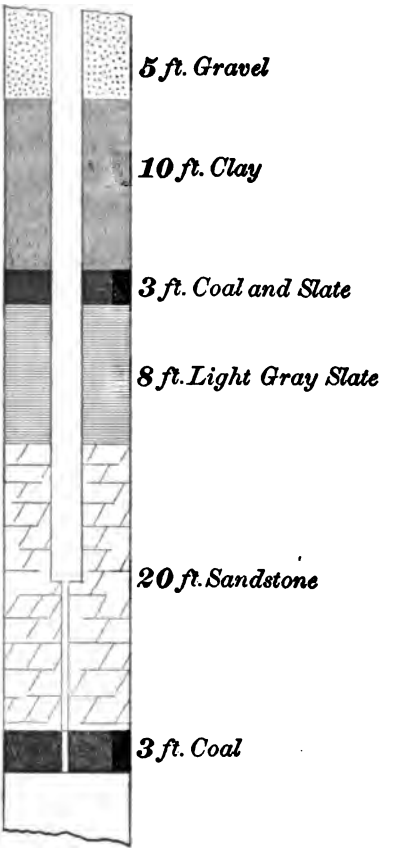
FIG. 5.



The coal has been hauled from the mountain to Breckenridge for blacksmith use. It is very sulphurous and very slaty. At the junction of Sandy and Hubbard creeks, northwest of Coal Mountain, and at an elevation of 1105 feet, a coal has been worked in the bed of the creek below water level. The coal from this bed has been mined and used by the blacksmiths; it is said to be purer and to burn much better than the coal from the Belknap bed. The bed was under water when I visited it, so that I could not see the coal. This bed occurs at a lower level than that at the foot of Coal Mountain. I should judge it to be a lower coal and very probably the representative of the Brazos coal-bed. Its thickness is very uncertain; it was variously reported to me to be from 1 to 6 feet thick.

8. On Mr. P. F. Pascall's farm, two and a half miles southwest of Crystal Falls, a well has recently been dug, and I was fortunate enough to obtain a record from the well-digger. The well was dug 39 feet deep, and a drill-hole 10 feet deep was sunk below the bottom of the well. The following is a section of the well:

FIG. 6.

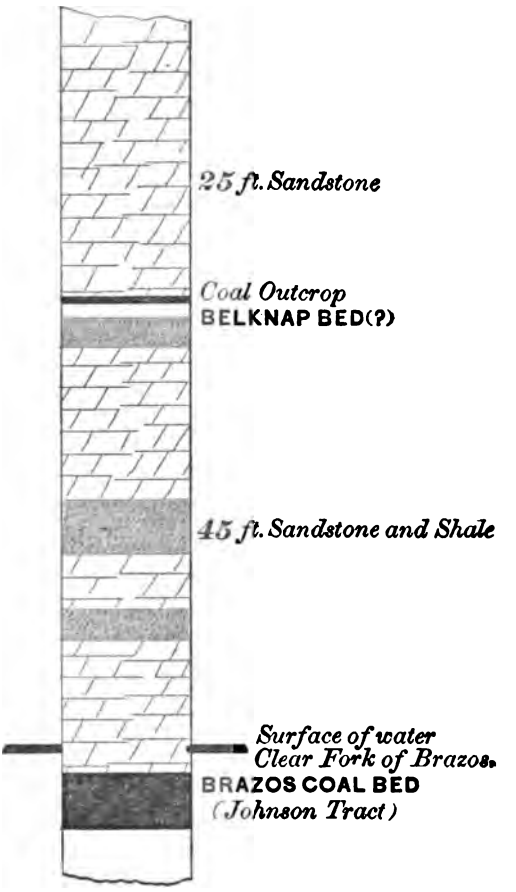


The elevation of the top of the well is about 1125 feet. The elevation of the first coal is 1107 feet, and of the second coal 1079 feet.

I believe the lower coal-bed which was pierced by the drill is the Brazos coal-bed. The upper coal, which is found associated with black slate, is very possibly the thin coal which is shown in the general section underneath the Belknap coal-bed. I am inclined to put this construction upon the well record from an examination of the rock exposures and topography in the immediate vicinity of the Pascall farm.

The most important outcrop visited in Stephens County was that of the Brazos coal-seam in the bed of the Clear Fork of the Brazos River in the eastern part of the Johnson tract, four and a half miles northwest of Crystal Falls. The coal lies 3 to 4 feet under the surface of the water in the bed of the creek, and is variously reported to be from 5 to 7 feet thick. The coal has been worked by prying large cubical blocks apart by a long crowbar and raising the blocks on to rafts by divers or tongs. The elevation of the top of the coal is 1075 feet. Forty-five feet above the top of the coal in the creek, which I have named the Brazos bed, and on the south side of the stream, is seen an imperfect outcrop of a coal which is probably the representative of the Belknap bed. The following is the section :

FIG. 7.



A hard massive gray limestone is found in the bed of the Clear Fork at Crystal Falls; in fact, it is the limestone which forms the natural fall of 4 feet 10 inches which has given a name to the place. This limestone underlies the Brazos coal-bed and is probably the base of the coal measures. The top of the limestone is only exposed in the northern part of Stephens County. By glancing over the elevations of the Belknap bed in the vicinity of Crystal Falls we see that the bed is nearly horizontal. The lowest point where it was found was at the Ballard opening on the Pinkney tract.

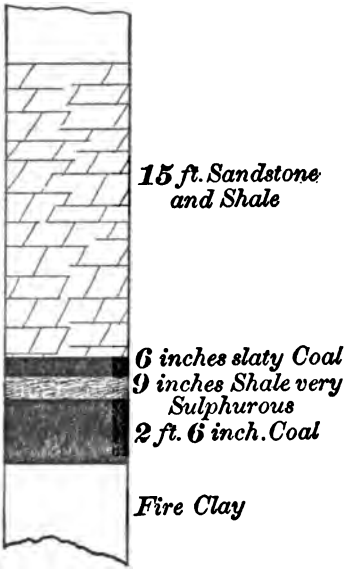
The Brazos coal-bed if it has an extended area should be found at Crystal Falls above the level of the creek, as the limestone in the creek occurs below the coal.

The area under which we might expect to find the Belknap and Brazos coals is very great. I found the limestone which occurs under the latter coal but a short distance west of Weatherford. The top of the limestone is not reached until we approach the Brazos River in Northern Palo Pinto County. Here the sandstone which is found over the Belknap coal-bed shows itself in the tops of the hills from 100 to 200 feet above the bottom of the valleys. If the coal-beds should be found on these hills the area would be too limited to make a development profitable. In Eastern Stephens County the sandstone is found more universally underlying the surface.

Going south from Crystal Falls to Breckenridge the topography resembles very much that in the eastern part of the county. The limestone for the most part is below the surface, and the topographical features are formed by the sandstone.

From Crystal Falls to Belknap, I found the sandstone generally beneath the surface until we descended into the valley of the Brazos River, about three miles southwest of Fort Belknap. There is no evidence against the existence of both the Belknap and Brazos coal-beds under most of the plateau between Crystal Falls and Belknap. The Belknap coal has been opened on several places on Whiskey Run, one and a half miles northwest of the settlement. About half a mile from the mouth of the run the following section is exposed:

FIG. 8.



The bottom of the coal-bed is 45 feet vertically below the town tavern and 50 feet above the bottom of the Brazos River. An indication of a coal-bed 8 or 9 feet above the Belknap bed is seen on Whiskey Run. It is possibly the same coal that was found above the Belknap bed in the vicinity of Crystal Falls.

A coal-bed has been opened at one time on the Brazos River near the mouth of Whiskey Run and 30 to 35 feet vertically below the Belknap bed. I did not see this bed exposed. It was reported to me to be 2 to 3 feet thick and of better quality than the upper bed. I was informed by the blacksmith at Fort Belknap that he had picked blocks of coal out of the bed of the river which had come from this lower coal-bed, which may prove to be the Brazos.

The elevation of the Belknap bed at Fort Belknap is about the same as it is at Crystal Falls, so that the coal-strata lie very nearly horizontal between the two places.

The Belknap bed is opened two and a half miles from the mouth of a small stream which empties into Salt Creek nine miles north of Graham. The coal is 2½ feet in thickness and has all the characteristics of the Belknap bed. Most of the territory lying between Belknap and Graham, and Graham and Crystal Falls, is underlaid by the Belknap and Brazos coal-beds. Whether they will ever prove to be workable commercial coal-beds in all this territory

can only be determined by actual tests and openings made on the beds.

The Brazos coal-field extends south to the Colorado River. There are many conflicting reports as to its boundaries. I gathered no facts outside of the immediate territory examined, so that I am not prepared to express an opinion as to its definite limits.

Coal has been reported to have been found in El Paso and Presidio counties along the Rio Grande, but nothing has been authentically stated as to the extent of the areas or the value of the beds.

Tertiary lignites, or lignitic coals, are said to exist in the following counties: Rush, Harrison, Cass, Grayson, Bastrop, Fayette, Caldwell, and Guadalupe.

Résumé.—The Brazos coal-field is the southwestern limit of the Missourian or Fourth bituminous coal basin of the United States. The coal-measures of Stephens and Young counties belong to the Carboniferous Age. The coal-strata proper are 85 feet thick, and are included between an upper sandstone and conglomerate, representative of the Millstone Grit or Pottsville conglomerate, No. XII of the Pennsylvania series, and a lower gray limestone representative of the Mountain limestone or Chester and St. Louis limestone of the Mississippi Valley. The coal-strata contain two coal-beds of workable thickness. The upper bed, named Belknap, ranges from 2½ to 4 feet, and the lower, named Brazos, from 4 to 6 feet. The coals are high in ash and sulphur, but have never been thoroughly tested. The Brazos bed underlies a great area, and will no doubt prove to be a valuable commercial coal in some localities.

NEW METHOD OF MAPPING THE ANTHRACITE COAL-FIELDS OF PENNSYLVANIA.

BY CHARLES A. ASHBURNER, PHILADELPHIA.*

DURING the early part of August, 1880, I was directed by Prof. J. P. Lesley, State Geologist, to assume charge of the geology and mapping of the Second Geological Survey of the anthracite coal-fields. I visited the region unincumbered by any instructions other than this,—that I should submit a plan for making the sur-

* In the practical application of this method I wish to acknowledge the valuable aid rendered by my assistant, Mr. A. W. Sheafer.

vey and of representing, in a practical way, by means of maps and charts, the geological structure of the coal-basins.

The methods which have been previously employed, of representing the general geological features did not seem to meet the demands of the engineer and operator of the anthracite mines. In order to make the work of practical value in coal-mining, it became necessary to devise some way of mapping the general structure of the basins and the minute details of the individual coal-beds. The mine maps of the region are so accurate and complete that it would be folly for any governmental survey to attempt, with the limited means at its disposal, to inform the individual operators or mine-owners of any of the characteristics of the developed areas of their coal-beds, which should be dependent upon accurate mine surveys.*

It became evident that it would be useless for the State to do any work unless it should be new and original, and give the anthracite interests information in the form of reports, maps, and sections, which were not already extant, and which should have a direct bearing upon the mining problems involved in the future development of the coal-basins.

There are wanted better and more accurate maps, and better and more accurate sections, both vertical and columnar, of the coal-strata than those that are now within the reach of the public.† It must

* Next to the surveys made by the United States Coast Survey, the mine surveys in the anthracite region are without doubt the most accurate of any of the extended surveys which have been made in America. I do not make this assertion without a thorough knowledge and appreciation of the other classes of work which have been done by the Government and by individuals in the United States. The surveys are made with the vernier, and the State law requires them to be carried to the face of the gangways and breasts and plotted to a scale of 100 feet to 1 inch every 6 months.

† About two months after the work was commenced it was judged advisable to publish a geological map of Schuylkill County, to accompany the maps, drawn to a scale of 2 miles to 1 inch, of the counties already completed It was thought that a map of this small scale could be easily and sufficiently accurately constructed from the following maps: Professor Rogers's Map of the Anthracite Coal-Fields, 1858, Map of the First and Second Anthracite Coal-basins, published by the Philadelphia and Reading Railroad Co., 1879, and Strauch and Cochran's Map of the Anthracite Coal-fields, 1879. I reduced each one of these maps to a uniform scale of 2 miles to 1 inch, and upon reproducing them on one sheet, I was very much surprised to find that there was no agreement between the geological lines limiting the coal-basins. Each one of these three maps is considered to be authoritative, as showing on a small scale the position of the coal-basins, yet they all differ. I was obliged to abandon the construction of the county map. I mention this fact in order to convey some idea of the accuracy of the *best maps* which are published.

be remembered that although the law requires the mine surveys to be accurately made and plotted, these maps are on a very large scale, are only of individual collieries, are disconnected, and are not accessible to the public. In some localities the mine-owners and operators deem it necessary for the protection of their interests to hold many important and general geological facts out of the reach of operators developing adjoining tracts. In order to collect, examine, systematize, and publish such valuable facts as shall be demanded by general interests, without jeopardizing the interests of the mine-owners, it is necessary that the work be done confidentially by disinterested parties. None can so well inspire the confidence of the mine-owners, and so well execute the work, as competent engineers and geologists employed by the State.

The demands which it seemed necessary to meet were threefold: First, to collect all the mining information concerning each colliery, such as the elevation of the coal outcrops, the dip and strike of the coal-bed, the thickness of the bed and its stratigraphical relations, the area which is exhausted and under development, and any special details connected with the methods of mining; second, to represent the geological structure of the areas where the position of the beds is known, either by actual workings in the beds or through tunnels, shafts, and drill-holes; and third, to represent the most probable structure of the areas undeveloped or unexplored.

In order to classify these facts in the most practical way for ready reference and use, it will be necessary to place them on maps whose scale shall be sufficiently large to allow of measurements being taken directly from them. To accomplish these objects, careful, conscientious work will be required. I have estimated, in a general way, that it will cost the State between $40,000 and $50,000 for the field and office work connected with the geological mapping alone.

To the practical anthracite mining engineer the question suggests itself: Will the advantages to be derived from such a survey plan warrant the necessary expenditure by the State to carry it out? I can readily appreciate the grounds upon which such a query would be based, for the same question has been put to me a number of times by some of the mining engineers in the region. I can conceive of no better answer to this question than to relate the substance of interviews had with two of the most prominent engineers connected with coal-mining in the United States. One is a past president of the Institute, a large individual operator, and an engineer

who, I can confidently assert, has made the most careful, systematic, and thorough mine surveys in the State; the other gentleman has been up to the present time the associate mining engineer of our largest anthracite coal-mining company. Both of these gentlemen when consulted prior to the commencement of the work doubted whether it would be possible for the State Survey to arrive at any results which had not already been attained by the mine engineers, and whether the Survey could publish any information which would be of practical value, and which would guide the mine operators and superintendents to a more economical and better method of mining.

The system of mapping which I am about to explain, and which has been approved by the State Geologist and Board of Commissioners, was first attempted in the office of one of the gentlemen referred to. For several days, during my absence in a distant part of the field, one of my assistants was engaged in mapping an area in the Pottsville Basin; on my return I found that the gentleman in whose office the work was being done had himself been mapping a difficult area. When I met him, he expressed no little surprise at what might be accomplished by the method, and assured me that if this plan of mapping was extended over the entire coal-field it would be quite possible for the Survey to teach the colliery managers much of practical value about the local geological structure of their coal tracts.

I had an interview with the other gentleman referred to for a second time after the completion of the Mahanoy-Shenandoah sheet. The underground contoured map, constructed to a scale of 300 feet to 1 inch, was critically examined in conjunction with the mine map of the same scale. After expressing delight with the system adopted, I was assured that if the State should undertake such work, the maps would be among the most valuable and practical of any of the results obtained by the Geological Survey.

The general method which has been adopted may be briefly stated as follows:

It is proposed to publish maps of all the coal-basins on sheets drawn to a scale of 800 feet to 1 inch ($\frac{1}{9600}$ nature), each sheet to cover an area of about fifteen square miles. On these sheets will be represented:

SURFACE FEATURES.

1. Railroads.
2. County roads.

3. Streams.
4. Outcrop of coal-beds.
5. Limit of coal-measures.
6. Towns, coal-breakers, etc.

UNDERGROUND FEATURES.

1. Underground contour-curve lines of the most extensively developed coal-bed in the individual districts (Mammoth bed principally). Contours 50 feet vertically apart.

2. Area worked out and area under development of contoured bed.

3. Gangways, tunnels, adits, airways, etc.,* of the contoured bed in a conventional color.

4. Gangways, tunnels, adits, airways, etc., of beds overlying and underlying the contoured bed represented by a conventional color and line for each bed.

A map containing these facts will be of the greatest value; it will show:

1. Area of coal-basins.

2. The area of the individual beds worked out and under development.

3. Area of the coal-basins undeveloped.

4. The structure of the basins where worked, with their rate of rise and fall in the centre.

5. The amount of coal available at different depths.

6. The most probable structure of the undeveloped areas.

The hypotheses and generalizations will be distinctly stated as such, and will be boldly separated from the known facts.

This system of representing underground structure in sedimentary beds was originated in America some twenty-five years ago by Professor Lesley. It was first employed in private reports for showing the structure of coal and iron properties. Professor Lesley has made constant use of the method wherever possible in his professional practice. Since the commencement of the Second Geological Survey several maps have been constructed for the exhibition of special structural features. Mr. Benjamin Smith Lyman has constructed underground contours on several maps of his private American sur-

* On the map published in report A^2 this material relating to the Mammoth bed was not defined; it has, however, been decided to add it on future published maps of the Anthracite Survey.

veys, and more recently has introduced the same method into the Imperial surveys of Japan. In most of these cases the contours have been largely sketched, being constructed on the basis of generalizations rather than absolute facts. Within the last two or three years, Mr. Eckley B. Coxe has used such contours, to a limited extent, for the definition of local mine dips.

The first time the system has been employed on an extensive scale has been in the construction of the mining geological sheets of the anthracite coal-field. The data which are available for constructing these maps are very extensive and very accurate. I have found the method to furnish the best means for interpreting the geological structure and the best way of representing it, so that in this the demands of the geological investigator are satisfied. At the same time that this end is accomplished, the facts relating to the structure of the coal-bed in the mines and adjoining undeveloped tracts are best classified and placed in such a form as to be of practical use to the mine superintendent and engineer.

In the course of constructing the map in the vicinity of Shenandoah and Mahanoy City (Plate I), many interesting problems in structural geology were suggested. Some of them were solved by descriptive geometry, others mathematically.

At some future meeting of the Institute I hope to be able to discuss at length some of the difficulties encountered, the means by which they were solved, and the bearing which they will have upon our present views of structural geology. At present it is my purpose to describe this system of mapping rather than to attempt an exhaustive discussion of the ways and means.

On the map accompanying this paper (Plate No. I) I have merely shown the contour of the floor of the Mammoth bed in curves 50 feet vertically apart. For the additional information relating to the plan of the mines, the area which is worked over in each bed, explored and undeveloped, reference must be had to the more detailed publications of the Geological Survey.* I simply wish to give the members of the Institute a description of the method which I have devised, with a few of its results and advantages.

The plan of construction was as follows: First, the surface and underground elevations were reduced to a common datum. In the case of the Mahanoy and Shenandoah sheet the datum of levels used is 4000 feet below tide. A sheet of tracing linen was placed

* See map accompanying report A^2 on Coal Waste.

directly over a map of the mines, drawn to a scale of 300 feet to 1 inch. The outcrop of the Mammoth bed was first drawn in. This was determined from outcropping points, from the position of air-holes, slopes, adits, and vertical sections through the mine works. The surface and underground elevations were then placed in position. After this, contour curves were constructed through the area of the Mammoth bed worked out and under development. The structure of that portion of the Mammoth bed was next defined which has not been worked, but which is overlaid or underlaid by mines in overlying or underlying beds. In the Mahanoy and Shenandoah districts the gangways have nearly a universal grade of about 6 inches in every 100 feet of length, so that a single instrumental elevation in a gangway afforded a means of computing the approximate elevation at any point. Where but few elevations have been determined, having a careful record of dip in a breast or slope between successive lifts in the mines, the levels were extended sufficiently accurately for the construction of 50-foot contour curves.

In the first case the area where the bottom bench of the Mammoth bed is worked out and under development is indicated by shading-lines drawn in a northwest and southeast direction, and of the top bench by similar lines having a northeast and southwest direction; the contours show the absolutely known structure of the bed.

In the second case the gangways, slopes, airways, adits, and shafts belonging to the beds over or underlying the Mammoth bed are represented,* so that the contours of the Mammoth bed below or above these workings, and which have been constructed from them, show the approximately correct structure of the contoured bed.

In the third case, the contoured area of the Mammoth bed lying between these two distinctly marked areas indicates the most probable structure of that portion of the coal-basins yet unexplored. No attempt has been made to classify these two latter areas on the accompanying sheet.†

By this method of classifying and representing the mining and geological facts upon one map, the structure of the basins, which is absolutely known, is distinctly separated from the structure which is hypothecated.

* These latter facts have not been placed on the map accompanying this paper.

† This map was reduced by photography by Mr. Julius Bien, of New York, from the original drawn to a scale of $300' = 1''$.

For instance, in the first case cited the structure indicated is actual, as it is determined from instrumental levels obtained in the mines. In the second case, the accuracy of the structure shown is dependent upon the parallelism of the Mammoth bed with the beds which are being worked in mines above or below the unworked Mammoth bed. In the third case, the contours have been drawn in hypothetically and are only provisional. The structure which is, however, indicated in the third case is worthy of consideration, as it is deduced from the greatest number of facts in surrounding areas which it was possible to obtain.

The information which a geological mining map constructed by this system contains, relative to the coal-bed which is contoured, may be classified under the following heads:

1. Elevation above tide of the coal outcrop.
2. Dip of the bed.
3. Strike of the bed.
4. Depth of the coal-basins.
5. Rate of fall or rise of the basins along their axes.
6. Position of the synclinals and anticlinal crests in the coal-bed.
7. Data from which a vertical cross-section of the bed may be made at any point across the basins.
8. Data from which the absolute surface area of the coal-bed may be obtained, and the coal tonnage of any special section estimated.

1. In order to obtain the elevation of the outcrop at every point, it is necessary that the bed should be contoured on a topographical map of the surface, as a basis.

2. The horizontal distance between the contour curves represents the cosine of the angle of dip.

To avoid overloading the map the degree of dip is not recorded in figures. The degree may, however, be readily determined by reference to the table given on Plate No. I, in which the relation is shown existing between the distance between the contour curves, to a scale of 1000 feet to 1 inch, and the degree of dip of the coal-bed.*

3. The direction of the contour curves shows the direction of the gangways which have already been driven, or the most probable direction which approximately level gangways will assume if driven beyond the present developed area.

4. The most probable depth of the coal-basins can be better esti-

* The scale which has been adopted for the survey sheets is 800 feet to 1 inch, while the scale of the accompanying illustations is 1000 feet to 1 inch.

mated by this method of construction than by any other. To illustrate this statement I wish to call attention to my determination of the depth of the Mahanoy basin, especially at that point lying between the Draper and Gilberton collieries, along section line No. 2. The workings on the south side of the basin in the Draper colliery extend down to a depth of 700 feet above tide (4700 contour curve); on the north side the elevation of the lowest working in the Gilberton colliery is about 650 feet (4650 contour curve); the horizontal distance between these lowest workings nearest section line No. 2 is 1900 feet. Having only these facts at hand the most natural way of determining the depth of the basin would be to continue the dip line in each colliery down to their point of intersection, and to consider the strata at the bottom of the basin to curve gently between the two dip lines as tangents, and above their point of intersection. By this method the bottom of the basin would be about 250 feet below tide. This seemed to be an excessive depth.

After the contouring of the Mahanoy basin from Mahanoy City west to Bear Run colliery had been completed, vertical cross-sections of the Mammoth bed were constructed across the basin 800 feet apart between the two localities. It was found, that in order that the general structural features which the sections showed east of Bear Run should continue to the west of this colliery, as they *probably* do, the bottom of the basin would not pass much below the tidal plane.

If this conclusion were accepted, several explanations might be suggested of the structure of the Mammoth bed in the centre of the basin. There might be one or more anticlinals in the centre of the main basin, or the dip of the coal-bed between the lowest workings in the two mines and the bottom of the basin might be less than the dip of the coal-bed in either of the mines. An anticlinal was first hypothecated, and the contour curves drawn in to represent it. When vertical sections were constructed across the anticlinal, the structure was found to be entirely dissimilar from that throughout the other portions of the Mahanoy basin, and as there were no facts to directly indicate it, the latter hypothesis of lower dips was assumed; this was found to better satisfy all conditions: the construction upon the map Plate No. I has been made in accordance with it.

There seems to be no universal law as to the sequence of dip in a coal-bed, from its outcrop to the bottom of the basin. In many cases the degree of dip seems to increase as we descend on the bed. This is more often found to be the case near the outcrop than the centre of the basin. In the slope of the Stanton colliery the Mammoth

bed dips 47 degrees near the outcrop. The dip at the first gangway 312 feet vertically below the top of the slope is 57 degrees. Between the first and second gangways the dip is 66½ degrees. The difference in vertical height is 281 feet. Below the second gangway the dip is 70 degrees; midway between the second and third gangways it is 65 degrees, while at the latter gangway it is 67 degrees. The third gangway is 271 feet below the second. I cite this case to show that the structure which I have adopted for this portion of the Mahanoy basin may not be the best. I believe, however, that since the bottom gangways on either side of the basin are so very much nearer the synclinal axis than the outcrop at the Stanton slope, that the dip of the bed below the lowest gangways should decrease, as I have indicated by the contour curves on the map.

5. The rate of fall and rise of the basins along their axes is a very important fact to determine in order to locate mining works, to develop the deepest portions of the basins. This special feature is admirably shown in the contour of the Ellangowan basin. The structure of this basin is, probably, more interesting than that of any basin in the Second anthracite field. The deepest part is directly under Bear Run, at the point where it crosses the axis. From this point it rises rapidly both east and west. To the east it bifurcates into two smaller and shallower basins, separated by a high, broad anticlinal. To the west the basin rises very rapidly, and ends in the Bear Ridge overturn. The William Penn colliery basin, which lies to the north of Bear Ridge, has been confused with both the Ellangowan and Shenandoah basins. As may be observed from the map it is a separate and independent basin.

6. It is a well-known fact to the practical mining geologist that the position of the crest of an anticlinal in a coal-bed is not necessarily vertically under the position of the anticlinal axis of the overlying and outcropping strata. Where the dip on both sides of the anticlinal is the same, such necessarily follows. Where the axial plane of the anticlinal is inclined, the axis in the outcropping strata may be many feet one side or the other of a vertical plane passing through the axis in the coal-bed. The distance depends upon the inclination of the anticlinal and the depth of the coal-bed below the surface. The anticlinal separating the Shenandoah and Ellangowan basins in the vicinity of the Yatesville colliery illustrates this fact. The Shenandoah and Bear Ridge overturns are extreme cases, illustrating the difference in the position of the synclinal axis in the coal-bed and outcropping rocks.

7. It is apparent that a vertical section of the contoured coal-bed may be constructed directly from the curves, running across the basin in any direction. The position on the section plane of the over and underlying strata may be located from columnar sections.

8. One of the most important applications of this method of construction is the estimation of the absolute areas of the coal-beds under any given tract, and consequently its coal tonnage. It is readily perceived that, when the contoured surface of the bed is developed or ironed out into a horizontal plane, allowance will have been made for every degree of dip which the bed possesses in its true position, and the real area of the bed on the flat will be shown.

The method of construction employed for the accompanying sheet (Plate III) of portions of the Shenandoah, Ellangowan, and Mahanoy basins was as follows: Vertical cross-sections of the floor of the Mammoth bed were constructed to a scale of 800 feet to 1 inch, horizontal and vertical, 800 feet apart throughout the entire basin. Five of these sections are shown on Plate II, constructed along the lines 1, 2, 3, 4, and 5 respectively of Plate I. Twenty-eight such sections were constructed across that portion of the three coal-basins represented on Plate I. Each one of these individual section lines along the floor of the Mammoth bed was developed into a straight line. The development was made on either side of a vertical plane which bisected the area of the sheet, as nearly as could be, between the outcropping limits of the Mammoth bed.* The developed position of the point of outcrop on each section was connected by a broken line with the point on the same outcrop on the adjoining section lines. In this way the developed areas of the coal-bed on the regular dips, on the overturned dips, and the area of the coal which has been eroded were inclosed. On Plate III are shown the development of each individual section and the area of the bed. The area of the bed eroded is indicated by north and south shading lines, of the bed on overturned dips by shading lines running northeast and

* The position assumed for the vertical plane is purely arbitrary. No matter what may be the relative position of the developed sections the resulting areas will in every possible case be the same. If the points of outcrop on the section lines should be connected by straight lines the area between any two sections would represent a trapezoid; the sides formed by the section lines would always remain the same length and the same vertical distance apart, and the area of the trapezoid would remain constant, no matter what might be the relative position of the section lines, so long as they remained parallel and 800 feet (in this case) apart. The sections are best developed on either side of a central plane passing through the coal tract, and then the shape of the developed area of the coal-bed will most nearly resemble the shape of the tract.

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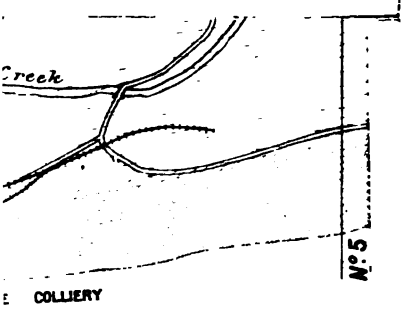

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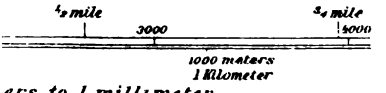

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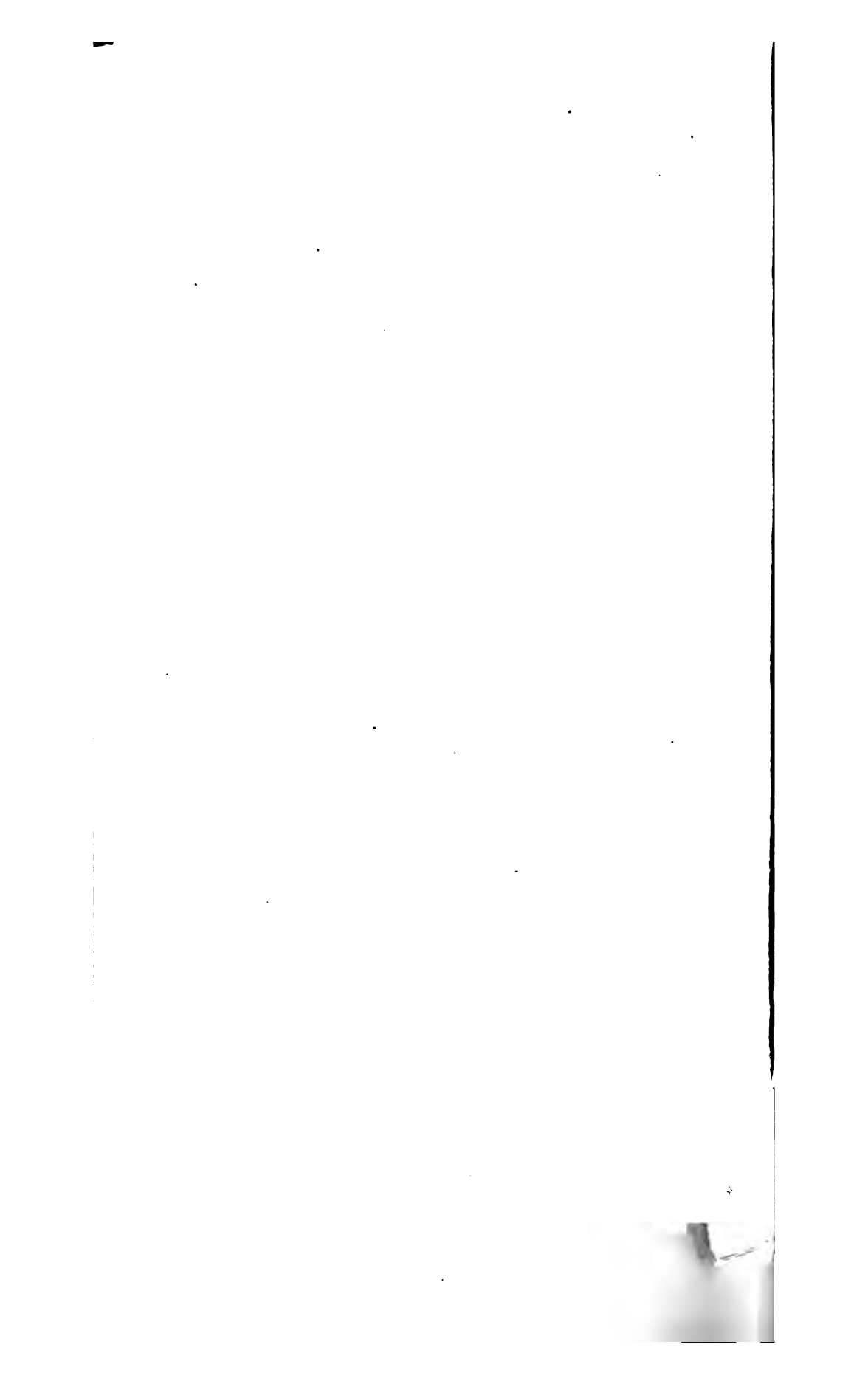
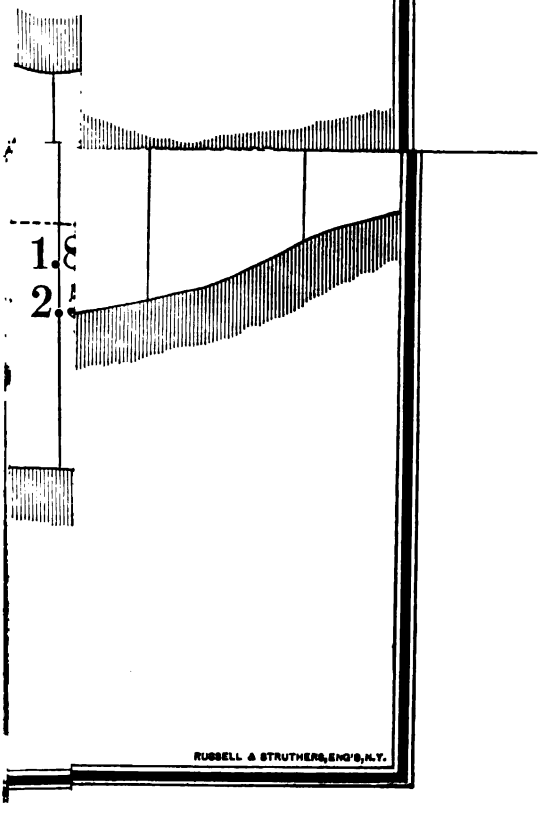


ER----PLATE III.

AL COAL BED

NA."A.



RUSSELL & STRUTHERS, ENG'S, N.Y.

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southwest. The unshaded portion of the sheet shows the areas of the bed having regular dips.

The tables give the areas, which are placed directly on the face of Plate III.*

REGULAR DIPPING MAMMOTH BED.

Shenandoah Basin.	Surface area	= 1132 acres = 1.77 square miles.
	Developed area	= 1425 acres = 2.23 square miles.
	Ratio surface area to developed area, 1 : 1.259.	
Ellangowan Basin.	Surface area	= 1964 acres = 3 07 square miles.
	Developed area	= 2300 acres = 8.59 square miles.
	Ratio surface area to developed area, 1 : 1.171.	
Mahanoy Basin.	Surface area	= 1163 acres = 1.82 square miles.
	Developed area	= 1604 acres = 2.51 square miles.
	Ratio surface area to developed area, 1 : 1.379.	

OVERTURNED MAMMOTH BED.

Shenandoah overturn, ...	181 acres.
Bear Ridge overturn, ...	54 acres.

ERODED MAMMOTH BED.

Near Shenandoah, ...	289 acres.
On Bear Ridge, ...	92 acres.
North of Mahanoy City, ...	111 acres.
Between Ellangowan and Mahanoy basins, . .	174 acres.
	27 acres.
	148 acres.

TOTALS.

Regular dipping coal.	Surface area,	4259 acres = 6.66 square miles.
	Developed area,	5329 acres = 8 33 square miles.
	Average ratio, 1 : 1.251.	
Overturned coal, ...		235 acres.
Eroded coal, ...		841 acres.

* In the first edition (*subject to revision*) of this paper the areas which were tabulated were computed by one of my assistants, Mr. H. I. Moyer. Recently I have had occasion to use Amsler's planimeter for the measurement of areas. I find it works with great precision, and is a much more accurate and rapid way of estimating the areas than that previously employed, of dividing the area up into triangles and parallelograms. Since the first computations the outcrop of the bed has been slightly changed, from additional facts which have been obtained, and the areas which are now given should replace those published in the first edition. The figures in the accompanying table are the mean results obtained from three determinations by the planimeter. From a series of tests which I have made as to the accuracy of planimeter determinations I find that the error lies within the following limits: minus $\frac{35}{100}$ths of one per cent., and plus $\frac{11}{100}$ths of one per cent.

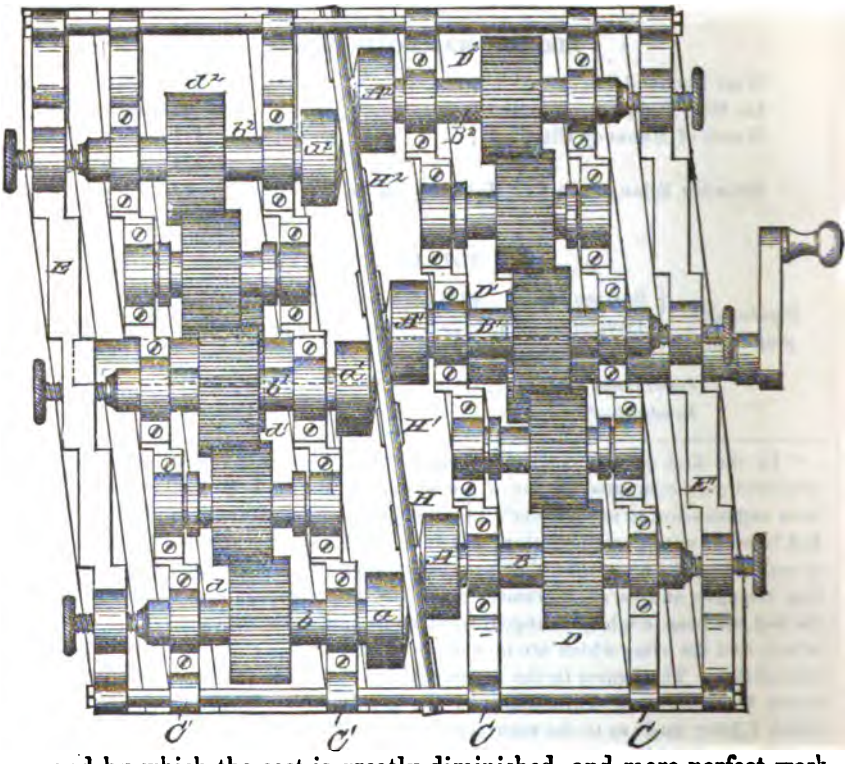
The coal tonnage which any particular tract or basin is capable of producing can be readily determined by multiplying the number of acres in the given tract or basin by the number of tons which experience teaches us can be produced from an acre of a coal-bed of a given thickness and known character. Those engineers in the anthracite region who have had very much experience in estimating the area of coal-beds and the tonnage which they are capable of producing to a given area will, I think, accord to this method greater accuracy than the approximating and averaging methods which have been so long and generally used.

BURNISHING AND DUCTILIZING STEEL.

BY JACOB REESE, PITTSBURGH, PA.

I HAVE discovered a new method by which steel and other metals may be burnished by the automatic action of the burnishing machine,

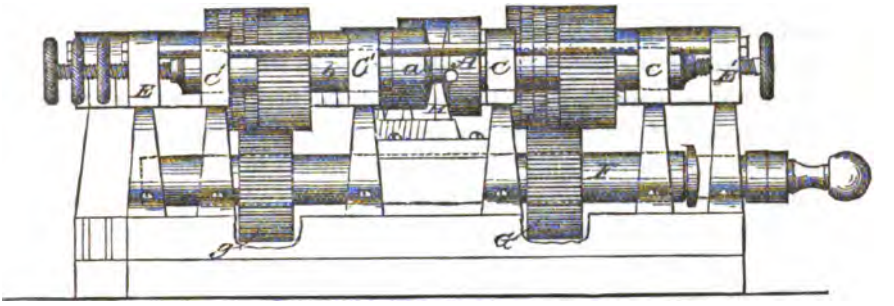
FIG. 1.



and by which the cost is greatly diminished, and more perfect work produced. And in addition to the polishing and burnishing action of

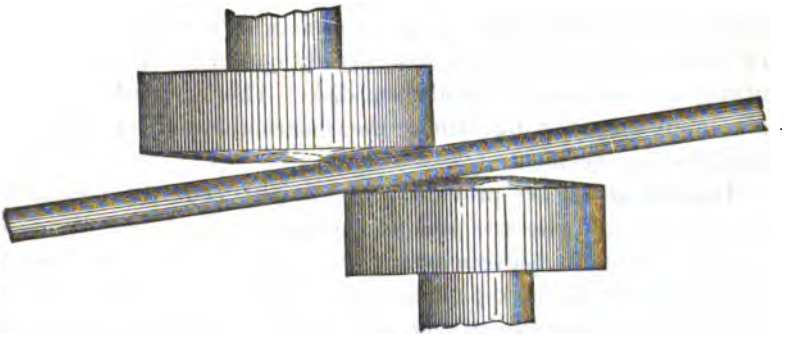
the new process, I have discovered that by a certain practice in the process of burnishing, the metal under treatment may be perma-

FIG. 2.



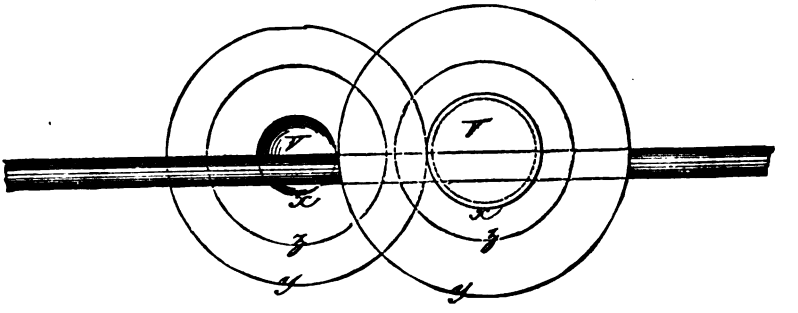
nently increased in diameter of its cross-section, and its ductility increased from 30 to 90 per cent., at a temperature ranging from 60° to 250° Fahr.

FIG. 3.



The machine is shown in the accompanying drawings. Fig. 1 is a top view of a continuous disk-machine, Fig. 2 is an end elevation of

FIG. 4.



the same, Fig. 3 is a top view of a set of conical disks, and Fig. 4

is a diagram, showing the working-face of one disk and the back of another. Like letters refer to like parts wherever they occur.

The series of disks, which in the present instance are six in number, are arranged so that they all operate upon the bar at one and the same time. The faces of the disks are slightly conical, and the centres of the faces are turned concave, so that the working-face of each disk extends from the edge of the periphery to the outer edge or line of the concave portion of the disk. The disks are of two sizes, the larger being about sixteen inches in diameter and the smaller about fourteen inches. The large disks, A A' A^2, are placed upon the same side of the working-line, and the small disks a a' a^2 are placed on the opposite side, the object being to secure a downward bite upon the bar by the large disks and an upward by the small disks, thereby keeping the bar down firmly on to the rests. These disks are mounted on suitable shafts, B B' B^2 and b b' b^2, which are set in the standards or housings, C and C', in such a manner that the large and small disks are not directly opposite to each other, but bear such relative positions as will bring the outer edge of the working-face of each disk directly opposite to the inner line of the working-face of the adjacent disk. This arrangement is not absolutely necessary, but renders the construction simpler than other modes of arrangement.

The disk-shafts are provided with pinions, D D' D^2 and d d' d^2, which mesh into idlers or pinions mounted on shafts, which are set into the standards between each pair of disks. It is necessary to have idlers for the disk-pinions to mesh into, because if they were to mesh into and communicate motion directly to each other every other disk on the same side of the working-line would revolve in an opposite direction, and consequently prevent the mechanism from working.

E E' are end housings, provided with suitable adjusting-screws for the purpose of setting the machine for any given size of work, to adjust the disk-faces in a parallel line and regulate the pressure upon the metal under treatment. F indicates the main driving-shaft, which is provided with pinions, G, g, which mesh into the central disk-pinions, D d. H H' H^2 indicate rests, which are set in line beneath and between the disk-faces. These guides or rests are slightly less in width than the diameter of the piece of metal to be operated upon, and for ordinary work they are adjusted to keep the centre of the bar a little below the centre of the disks, that being necessary in order that the resultant action of the forces exerted by

the movement of the disks may cause the bar to feed forward as it rotates. The forward speed will depend upon the altitude of the rests in relation to the disk-centres, and if they are adjusted so that the centre of the bar is on the same line as the centre of the disks it will rotate, but without forward or backward motion. If the rests are adjusted to throw the centre of the bar above the centre of the disks, it will have a backward movement as it rotates.

When power is applied to the main shaft, *F*, to rotate the same the pinions, *G g*, communicate motion to the central disk-pinions, *D d*, which turn the idlers, and thus communicate motion to the other disk-pinions, causing all the disks to rotate uniformly. In order to fit these disks for burnishing and ductilizing iron and steel it is necessary that their working-faces should be trued and highly polished, and this I accomplish in the following manner:

The machine having been adjusted for any given size of work and the guides or rests being in a line and adjusted to the proper height, I take a square piece of hard wood of suitable thickness and place it upon a rest in front of the machine. The disk-faces are then oiled and sprinkled with emery, and finally the block is entered between the disk-faces, when it will be caught and drawn slowly forward, thus truing and polishing the entire train of working-faces at one and the same time, and also polishing and truing the working-faces of the rests. The machinery is now capable of burnishing and ductilizing the metal when properly adjusted for that purpose, and this adjustment is a matter which will require considerable skill and care upon the part of the operator, as a degree of pressure is necessary in some cases which would be entirely inadmissible in others.

By referring to the drawings it will be readily understood that when the rests are adjusted to any given height the feeding of the bar will be uniform and constant, and therefore the only method of increasing and decreasing the frictional action upon the surface of the metal will be by regulating the pressure as occasion may require. The greater the friction the greater will be the tractive force which tends to draw or film the surface of the metal. The ability of the metal to resist this drawing force depends upon the attraction of cohesion of its particles. This varies in different metals and in the same metals at different temperatures, being greatest at the lowest and least at the highest temperature; and in iron and steel it depends greatly upon the amount of carbon in combination with the metal. Now, it is evident that when the bar is put into the machine its temperature will be gradually raised by the frictional action at

each successive pass, and therefore become less and less able to resist the tractive force, and that as its temperature increases the metal will gradually expand in diameter, so that if all the faces are previously adjusted to exactly the same distance apart, not only will the metal become less able to resist the tractive or drawing force, but the increased temperature of the metals will, by causing such expansion, develop more pressure and frictional tractive force, so that the metal will then be very liable to draw or scab. The disk-faces should therefore be so adjusted as to bring the greatest pressure at the first pass, and to apply a little less at each successive pass until the burnished bar is completed.

In conducting the operation the object is to secure sufficient pressure to compress the inequalities and to develop enough frictional or tractive force to overcome the attraction of cohesion of the particles composing the scale on the surface of the metal, yet not enough to overcome the force of cohesion of the particles which will then form the surface of the metal itself. If the metal has a great force of cohesion and does not possess a tough, tenacious scale, this may be readily effected; but where the conditions are opposite great care must be had and a constant watch kept for signs of filming. Therefore, as it is imperatively necessary that certain degrees only of pressure, frictional action, and tractive force be applied or developed upon the surface of the metal, it is necessary, first, that the metal should have been previously rolled to an exact or uniform gauge, so that when burnishing an undue amount of pressure may not be developed upon its surface at any point; secondly, as the ability of the metal to resist the tractive force is less when at high temperatures, it should be operated upon when in a cold state, or at a temperature not exceeding 500° F.

The machine being in condition, having its working-faces trued and polished, and the metal having been properly prepared by rolling to an exact gauge, a test-bar may be entered and the working-faces gradually tightened up after each pass until a point is reached at which the films begin to show upon its surface. This is an indication that the pressure is too great, and the tightening-screws should be relieved a little and the test-bar again entered, a careful watch being kept for further filming. If none appears the machine is properly adjusted for that sized bar; but if films still continue to form, the pressure must be further decreased until a point is reached at which no films are formed. It is not necessary, however, that the machine should always be adjusted in the manner just described, as

burnished bars may be sometimes produced although a very light pressure is used, as, for instance, where the scale upon the metal is not tenacious and the surface of the metal is very smooth; but in all cases the pressure will be light in comparison with that which is required for rolling, and extremely light when compared with that required for cold-rolling. I am unable to give the required degree which will be necessary in all cases, as I find that the pressure varies upon any given point according to the difference in the diameters of the bars operated upon, the larger diameters burnishing under heavier pressure than the smaller; and, moreover, the pressure upon any given point may vary accordingly as the width of the burnishing-faces used varies. The wider the disk-faces the greater will be the amount of frictional action and tractive force upon any given part of the bar in any given time, and consequently the less must be the pressure. The converse of the proposition is also true, viz., the narrower the disk-faces the less the frictional action and the greater the pressure admissible; but the working-faces must never be made very narrow, as in such case so great a pressure would be required to develop the frictional action which is necessary that the operation would be entirely changed, and cause a reduction of the metal and displacement of its particles, as in rolling. Finally, I find that the pressure may vary with the different temperatures and natures of the metal operated upon. Therefore, no precise rule can be adhered to for all cases, except, first, to have all stock previously rolled to a uniform gauge; secondly, to have all the burnishing-faces turned perfectly true with a high polish; thirdly, to have the burnishing-faces constructed of sufficient width to develop a sufficient amount of frictional action when a light pressure is applied. Then feed the bar at a proper temperature, and apply the pressure from an exceedingly light one to the highest the metal will stand without filming.

The machine being in the condition specified and adjusted as specified, rough bars of metal in a cold state are inserted, one at a time, between the receiving-disks. They are caught, rotated rapidly, and drawn forward, travelling with a speed of from one to sixty feet per minute, according to the size of the bar, height of the rests, and speed at which the disks rotate, and are delivered perfectly straight, of a true cylindrical form and highly burnished. In some cases, however, when the bars are of a large diameter, and are covered with a tough, tenacious scale, additional passes may be required to accomplish this result.

When burnishing cold metallic bars I prefer to place narrow

pans, containing petroleum or other oil, beneath the second and third pair of disks. These pans are of sufficient size to contain the required quantity of oil, and are shaped so as to form a sheath or trough, in which the lower portions of the disks revolve. The effect of the application of the oil is to prevent the working-faces of the disks from scratching and marring, and it also has a certain effect upon the finished product, of which I shall speak hereafter.

When it is designed to straighten and burnish metal directly as it comes from the rolls during its manufacture, the process should be the same as before specified, except that the metal should be allowed to cool to a dark-red heat, and a considerable quantity of water should be let upon the first set of disks and upon the bar, to reduce the temperature of the metal to the proper degree, so that in its rapid contraction the scale will be loosened. A steam or air blast should be used to carry the scale away, and the first and second set of disks will then readily remove any portion of scale which may still adhere to the bar. The metal will then pass from the first to the second set of disks, thoroughly cleaned and partially burnished, and the second and third pair of disks will, by the frictional action, which also burnishes, heat the surface of the bar. Consequently, the lighter components of the oil will be vaporized, leaving the bar coated with carbonaceous matter, which is apparently forced into the pores of the metal by the action of the disks, and the bar, when burnished, is found to have a much finer appearance than if it had been burnished without the oil, and it is also enabled to resist oxidation to a greater degree.

For the purpose of illustrating the frictional action which may be obtained by the employment of disk-rolls, I will again refer to the drawings, in which Fig. 3 represents a top view, and Fig. 4 is a diagram, of a set of disk-rolls, the latter showing the back of a sixteen-inch and the working-face of a fourteen-inch disk. *V* indicates the concave portion of the disk-faces, which is five inches in diameter in the fourteen and seven inches in diameter in the sixteen-inch disk. *x* indicates the inner lines or edges of the working-faces; *z* the neutral lines, or those portions of the disks at which their rate of speed when working is equal to the surface speed of the bar in rotating; and *y* the outer edges or lines of the working-faces of the disks at their peripheries. It is well understood that the different portions of the disk-faces travel at different rates of surface speed, according to their position with relation to the disk-centres.

When a cylindrical bar is fed into the disks it will rotate, and, all portions of the surface of the bar being at the same distance from the axis or centre, will travel at the same surface rate of speed, and as the working-faces of the disks travel, having differential rates of surface speed, as before stated, great frictional action is produced on the working-surface of the disks and the surface of the bar; or, in other words, this result follows because the surface speed of the bar and disk-faces is the same only on the theoretical or neutral lines indicated by the letter *z*, the disk-faces travelling at a gradually increasing speed from the neutral line to the peripheries, and at a gradually decreasing speed from the neutral line to the inner lines of the working-faces of the disks. If, therefore, as in ordinary practice, the working-faces of the disks are four inches in width from the outer to the inner edges of the working-faces, the area of the small disk will be $113\frac{96}{1000}$ square inches, and that of the large disk $138\frac{220}{1000}$ square inches, thus making a total area of $251\frac{816}{1000}$ square inches of frictional surface which slips or rubs over the surface of the bar at each revolution of the disks.

In addition to the frictional action of the disk there is that of the rests. A bar one and one-eighth inch in diameter will rotate (the rests being at the proper height) eight times to each revolution of the disks and feed forward about two inches to each revolution of the disks, or one-quarter of an inch to each revolution around its own axis. The length of the rest's working-surface is usually about five inches, so that the bar will revolve twenty times over the polished surface of the rest during the time any given portion of it passes from one end to another of the rest; and the rest acts the same as if the bar were rotated in a lathe and a burnishing-tool pressed against it with the same degree of force during twenty revolutions around its axis. Finally, there is the frictional action which arises from the forward movement of the bar over the burnishing disks and rests.

One of the effects produced by the frictional action to which I have referred, or by the action of the heat developed by the friction, is to gradually expand the metal during the burnishing operation, so that as the bar travels forward the pressure will become augmented, unless the tightening-screws are adjusted lighter for the latter passes; and I have found that, when they are properly adjusted, the metal will in some cases retain permanently its increased diameter, which I have found in all cases to indicate a slightly decreased tensile strength, elastic limit, and a greatly increased duc-

tility in the metal. When, however, the tightening-screws were adjusted so as to compel the bar to retain its original diameter, I have found the elastic limit and ductility are the same as in the original state, and that the tensile strength remains almost the same as in the original state previous to the operation.

The following record of tests made by tension shows clearly the changes which are effected in the physical nature of the metal by the process:

Marks and Condition of Pieces.	Original Diameter.	Diameter after Fracture.	Original Cross-Section.	Cross-Section after Fracture.	Elastic Limit.	Elastic Limit per Square Inch.	Tensile Strength.	Tensile Strength per Sq. Inch Original Section.	Elongation in Five Inches.	Elongation.
	In.	In.	Sq. In.	Sq. In.	Pounds.	Pounds.	Pounds.	Pounds.	In.	Per Cent.
459 Rough, ...	1.013	.955	.806	.716	51,000	63,283	88,235	109,486	.547	10.9
460 Bright, ...	1.014	.853	.807	.571	47,500	58,823	86,795	107,486	.953	19.0
461 Bright, ...	1.016	.851	.811	.569	49,500	61,058	88,395	109,035	.797	15.9
462 Bright, ...	1.012	.969	.804	.737	48,000	59,674	88,805	109,782	.500	10.0
463 Bright, ...	1.015	.910	.809	.650	47,500	58,704	87,365	107,972	.656	13.1
464 Rough, ...	1.012	.952	.804	.712	48,000	59,674	87,500	108,782	.500	10.0

Nos. 459, 460, and 461 were cut from the same bar of steel. No. 459 was cut from the rough end, which was in the same condition as it came from the rolling-mill. Nos. 460 and 461 were bright, and were cut from the end that had been burnished. No. 459 broke just above the top centre punch-mark. No. 460 broke between the points of measurement. No. 461 broke at the top centre punch-mark.

Nos. 462, 463, and 464 were cut from one bar of steel, each end of which had been burnished. No. 464 was cut from the middle of the bar, which was rough as it came from the rolling-mill. No. 462 was cut from one end, and No. 463 from the other end, both of which

had been burnished. No. 462 broke one and one-half inch above the top centre punch-mark. No. 463 broke one-half inch below the top centre punch-mark. No. 464 broke one inch above the top centre punch-mark. No. 462 did not break at its smallest diameter, which was midway between the points of measurements.

All the changes or phenomena which present themselves in the finished product show that the operation to which it has been subjected embodies some principle which has never before shown its effects in the product of any rolling, hammering, or compressing operation, nor in the product of any burnishing, brightening, or polishing operation known heretofore to the art of metallurgy. For instance, that indicated by the permanent increase in the diameter of the metal, although at the time it is confined between parallel surfaces and under pressure, the operation being conducted so that the heat developed does not generally exceed 250° Fahrenheit, which would not be sufficient, no matter how long continued, to anneal or ductilize heavy cold bars of steel by any known process.

When steel is required for structural purposes it must be able to resist concussion, sudden shocks, rapid vibration, and deflection, and give due warning, before final rupture takes place, by elongating within certain degrees. Consequently, heretofore, the steel has been made low in carbon to secure the required ductility, and therefore possessed a low tensile strength. This steel is annealed after its manufacture, to bring it back to its normal condition, and destroy in a measure the effects produced in its physical structure by the ordinary rolling operation, since all rolling, hammering, and drawing leave the physical structure of the metal in an abnormal condition, producing hardness, brittleness, and liability to rupture from concussion, vibration, or rapid deflection.

Annealing steel reduces its ability to resist tensile, compressive, and torsional strain, as well as its elastic limit, and increases its elongation or ductility. It is a slow operation, lasting generally from five to twenty-four hours, and leaves the metal covered with scale. By my process the ductility of the metal may be greatly increased without the formation of a scale upon its surface, and in a very rapid manner. In comparing it with ordinary annealing operations the following facts become apparent:

First. As the metal is previously rolled to an exact size, and the disk-faces are adjusted to exert exactly the same degree of pressure and frictional action upon all parts of the bar, the ductility of the metal should be constant and uniform at all points, whereas in an-

nealing the temperature of the furnace varies at different parts, consequently the metal cannot be uniformly annealed.

Second. As the bars are all of the same size previous to the burnishing operations, the same degree of ductilizing action should be had upon each, and consequently they should all be regularly ductilized, whereas in annealing the process is not automatic, and the bars are charged and drawn by hand, so that they are exposed to heat for irregular periods of time.

Third. The ductilizing effect is produced by this process at a heat never exceeding 500° Fahrenheit, and this is too low to deprive the bar of carbon; or, if it does so to any extent, it does it uniformly, whereas in annealing the bar loses considerable carbon, and loses unequally, so that not only is the tensile strength reduced considerably, but it varies at different points of the bar.

Fourth. As the ductilizing of the metal is constant and uniform, its internal strains should be regularly and uniformly relieved, whereas in annealing the temperature always varies in different parts of the bar; hence its internal strains should be irregularly relieved.

Fifth. As the temperature in this process is very low and uniform upon all parts of the bar it remains perfectly straight in cooling, whereas in annealing the high and uneven temperature of the metal causes it to warp and become distorted in cooling.

Sixth. By this process I am enabled to ductilize metal at the rate of one foot per second to one foot per minute, whereas annealing operations require several hours or days for their completion.

This process will be found to be peculiarly adapted to the production of steel shafting, piston-rods, and also for very light work, such as burnished steel for pivots for watches, clocks, etc., in which latter case it is evident that the mechanism employed must be of a reduced size suitable for the work to be accomplished.

Comparing the mechanical effect of this process with other well-known processes, the difference is very marked. Wrought iron, possessing a tensile strength of 50,000 pounds per square inch, and an elastic limit of 30,000 pounds per square inch, and exhibiting an elongation of 25 per cent., will, when cold-rolled by the Lauth process, possess a tensile strength of 68,600 pounds, and an elastic limit of 59,600 pounds, but the ductility is reduced to an elongation of 6 per cent. When such cold-rolled iron is annealed it is found to possess a tensile strength of 48,700 pounds, an elastic limit of 32,000 and an elongation of 15 per cent.

Professor R. H. Thurston, in his paper on "Mechanical Treatment of Metals,"* said: "All known and actually practiced methods of so altering the character of the metals used by the engineer, involve, directly or indirectly, the elevation of the original elastic limit of the material." In this process, however, the elastic limit is slightly reduced.

In conclusion I would add, that the phenomena exhibited in this process invite further research into the laws of molecular physics.

DISCUSSION ON STEEL RAILS.†

ASHBEL WELCH, LAMBERTVILLE, N. J.: Dr. Dudley has given the wear of steel rails under four different conditions. He arrives at the conclusion that the softer rails, or those that from their composition ought to be softer, wear better than the harder. But there is another condition which has an important bearing on the subject, and should not be overlooked,—the weight on a wheel. With the lighter weights of the past, the softer rails may have worn best; with the heavier weights of the future, the harder may wear best. Weights will probably be increased up to the capacity of steel to bear; then doubtless the harder steel will wear best.

A leaden rail with ten pounds on a wheel might carry millions of tons, but with one hundred pounds on a wheel, it would be destroyed by a few thousand tons. So in the days of iron rails, my experience was that the softer rails under light machinery stood better than some of the harder; but under heavy machinery the softer were much the most rapidly destroyed. It is doubtless the same with steel.

The pounding motion of the wheels loosens or spreads the particles of a thin film of steel; the pull lengthwise on the rail de-

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* Metallurgical Review, vol. i, page 1.

† The remarks as here given, as in the previous discussion on steel rails, have all been written out or revised by the participants in the discussion, and represent, therefore, their mature views. It has been thought that this plan, when it can be carried out without doing any of the speakers injustice in debate, is much to be preferred to a strictly verbatim report. The remarks of Mr. Chanute were sent to the secretary after the meeting, and although they did not form a part of the actual discussion, there can be no doubt of the desirability of including them in this report. The papers under discussion were "Rail Specifications and Rail Inspection in Europe," by C. P. Sandberg; "The Wearing Capacity of Steel Rails in Relation to the Chemical Composition and Physical Properties," by C. B. Dudley, and "Rail Patterns," by A. L. Holley.

T. M. D., *Secretary.*

taches or scrapes them off. The softer the metal the more liable the particles to spread or flow sideways; the more brittle, the more liable the particles to break loose. With light machinery flowing may be practically nothing, with heavy machinery it may be enough to wear the rail out very rapidly. At a certain point doubling the weight might increase the flow tenfold. The harder the metal without decrease of tenacity or increase of brittleness, the better we should expect it to wear. All may depend on what is left in or used to make it hard.

Dr. Dudley's observations give us incidentally the difference in wear per million of tons carried, caused by difference of weight on a wheel. On the south or loaded track the gross tonnage was 8,000,000 per annum, on the north or light track 5,000,000. As about the same number of wheels must have gone one way as the other, the average weight on a wheel must have been sixty per cent. more on the loaded track than on the light. The wear per million of tons gross load, as found by summing up the wear on each rail, averages 31 per cent. more on the loaded than on the light track. So in this case the wear per ton of gross load increased as the 0.5 power of the weight on a wheel. With iron rails in former years it increased much faster than this rate. As machinery becomes heavier it will doubtless increase faster with steel.

As the same engines and tenders with the same weights on a wheel passed over each track, and as the speeds were probably greatest on the light track, the difference in wear due to difference in weight on the freight-car wheels was probably greater than above estimated. The former weights on a freight-car wheel were about $(\frac{20000+30000}{8}) = 5000$ pounds. The weights now coming into use are about $(\frac{24000+40000}{8}) = 8000$ pounds, an increase of 60 per cent. over the weights when the wear reported took place. This may entirely change the relative rates of wear of hard and soft steel.

Several interesting inferences seem to be deducible from Dr. Dudley's observations, but I confine myself to the single point I have made. Ten years ago I found the wear of steel on the roads between Philadelphia and New York about 50 per cent. more than Dr. Dudley found it on his road. This is accounted for by the better roadbed and smaller proportion of passenger trains at high speed on the Pennsylvania Railroad, by the narrow-gauge cars on wider-gauge roads as it then was, and especially by the steel rails between here and New York being then only in the worst places.

The softer Sheffield rails made from Swedish pig wore better than either of the two harder kinds I got from France.

Dr. Dudley's conclusion seems to be that rails should approach the condition of Bessemer iron. I found that the wear of iron rails from Bethlehem was about 25 per cent. more than that of steel from Sheffield, laid in the same track and under the same circumstances. This, however, does not show the relative durations of the rails, for steel owing to its elasticity is only injured on the surface, and will wear till it is reduced to a skeleton; while iron is affected all through by each blow, and will finally go to pieces before it is worn down. The point I make is, that though the softer steel may have worn best under the lighter machinery of the past, it does not follow that it will wear best under the heavier machinery of the future.

The patterns of steel rails now displayed, and the papers of Mr. Sandberg and of Mr. Holley, with the allusion that has been made to the history of the now accepted forms, make it proper to give a short historical notice of the first rails which had certain characteristics common to all these patterns, and of the principles on which they were made.

The early steel rails, copied after the iron, had very heavy bases and stems, and no flat surfaces for fishing. One fifth to one eighth of the metal put into them did little or no good, and the fish-splice, then coming to be recognized as the best, could not be used to advantage. The useless weight made steel rails so expensive that they came into use very slowly. In 1865 I made a pattern to avoid these faults, guided by the following considerations: The theory then was, and I suppose is yet, that a blow on iron such as that given by a locomotive wheel, is felt all through the metal, and produces a permanent though minute disintegration or change of form, the accumulations of which must in time weaken and *unweld* the base and stem as well as the head of the rail, and so extra metal must be put into the lower part of the rail to compensate for this gradual weakening; but that in steel, owing to its elasticity, such a blow produces no permanent effect on the metal except at the surface. Therefore the stem and base of steel may be very much lighter than of iron, not only on account of its greater strength and freedom from welds, but also from its immunity from deterioration by use. Hence all the metal possible should be in the head where the wear is; and as little as consistent with safety in the stem and base where there is no wear, and with steel, no deterioration. In England, where the supports are far apart, strength and stiffness are

primary considerations; in this country, where the supports are close together, other considerations engross attention. The width of the base should be determined by the endurance of the wood it is to set on, and for this purpose must be much greater than is necessary for strength or to prevent upsetting.* Partly from calculation and partly from observing the behavior of iron and steel in circumstances somewhat similar, I made up my mind that three-eighths of an inch thickness of stem was ample to bear the weights and the shocks, vertical and lateral, of the machinery then in use; and that an eighth thickness at the edge of the base was sufficient to transmit to the wood all the pressure its fibres would bear.

In accordance with these views, but conceding something for the sake of abundant safety and the facility of manufacture, I made a pattern with 4 inches height, 4 inches base, head 2⅜ wide × 1¼ deep, stem 7-16 thick, and edge of base 3-16 thick; weighing 53 pounds to the yard. Assuming that fishing made the best joint, I made (as I had previously done in very slender iron rails) the under side of the head and top of the base plane surfaces, as broad as possible, so as to give a perfect and broad bearing to the edges of the fish-plates, and as near horizontal as possible, so as to lessen the tendency of the fish-plate to work out by the jar.

This pattern was condemned by every engineer to whom it was shown, on the ground that it was too weak and could not be rolled. I was fully aware of the difficulties of manufacture, but was confident they could be overcome. In one point I yielded too much to the manufacturers; rounding off the corners on the under side of the head.

After long negotiations an order for 200 tons for trial was accepted by Naylor & Co., in August, 1866, and sent to England to be executed. There everybody that saw it condemned it, and for several months John Brown & Co. refused to roll a rail of such a preposterous shape. As I wished to have an extreme test of the correctness of my ideas, I insisted on the performance of the contract. At last the rails were rolled, tested by Kirkaldy in London, and in the spring of 1867 laid down in some of the hardest places between this city and New York. Several hundred tons of the same pattern were laid the next season. I continued to watch and test them carefully for eight years, and so far as I could find not one ever broke, bent, or compressed in the stem, or gave out in any other way.

Thus the principles on which this pattern was made, and its proportions with the machinery then in use, were shown to be correct

as seen from the consumers' point of view. It had as big a head and wore as long, and was as free from accident as previous steel rails twenty per cent. heavier. Some manufacturers in this country condemned the pattern because, without trial, they believed it could not be safely rolled. But John Brown & Co., after trial, believed it could be, and showed their confidence by soliciting an order for ten thousand tons more of the same pattern.

The principles of this pattern, with the proportions slightly modified, were gradually, and are now generally adopted. Mr. Hinckley after a year's observation, adopted the pattern with a very slight addition to the metal below the head, and in 1868 relaid one track with it from this city to Baltimore, where the rails may still be seen.

In 1874 Mr. Chanute on the Erie, and Mr. Sayre on the Lehigh Valley, simultaneously and without concert, adopted the sloping sides of the head, which important feature is now in general use.

In 1870 Sandberg's patterns were published, embodying the same principles with the angles and proportions slightly different. Whether he knew what had been done before I do not know. Doubtless the same considerations on which I acted occurred to many others.

As the machinery is now much heavier than in 1866, and steel not now so good as that made by John Brown & Co., from Swedish pig, and as the price of steel is very much lower, a small saving in weight is of less importance. I have nothing to say against the somewhat heavier proportions now generally used—for example $\frac{1}{2}$-inch stem instead of $\frac{7}{16}$ and $\frac{1}{4}$-inch thickness at edge of base instead of $\frac{3}{16}$.

In Sandberg's new patterns of 1878, he has, however, adopted almost the identical proportions I used in 1866. His thickness of stem is exactly, and thickness of the edge of the base is very nearly the same. His fishing angle, which in 1870 was 22° is now 30°—mine was always 28°. It is gratifying to find that so able an engineer, after so wide and so long experience, has within the last three years settled down upon the proportions I adopted fifteen years ago, and which before they were tested were so universally condemned, especially in the very dimensions now adopted by him.

I think Sandberg's heads are too convex, and his bases rather narrow. In America bases are always far wider than stiffness and stability require; the practical question being what width of bearing does the timber require. Where chestnut ties are used the base should be not less than four and a half inches. There is therefore little practical relation between the height and base.

The old plan was to increase every part of a rail much in the same proportion. But each part should be in proportion to what it has to do. The head should be deep in proportion to the amount of traffic and the lowness of the rate of interest on its cost. The body need only be strong enough to carry the head after it is well worn down, and that depends on the weight of the machinery, and in the case of steel has little to do with the volume of traffic, except so far as that affects weight of machinery. As on most railroad systems, the same machinery is used on main lines with heavy traffic, and branches with light, I suggested in 1874 that each system adopt the same body of rail for both, and make the head deeper on the main lines, shallower on the branches. This plan was adopted on the Pennsylvania Railroad. Sandberg seems to recognize this in his patterns of 1878.

R. W. HUNT, TROY, N. Y.: Again Dr. Dudley presents to our consideration a series of most carefully conducted experiments, and while I fully appreciate the labor and thought this work has cost him, I must still hesitate to accept his deductions.

This paper differs from the previous one in that it deals exclusively with the wearing qualities of steel rails. Dr. Dudley gives his reason for this change in the following statement: "With the improvement in maintenance of way which has characterized the Pennsylvania Railroad during the last five or six years, the removal of rails from the track from the first two of these causes (*i. e.*, broken and crushed) has, if I am right, quite notably diminished. This certainly is true with regard to broken rails. And if, as time advances, the number of crushed rails shall diminish, both because of the continued improvement in maintenance of way before referred to, and because, owing to improved and better methods at the steel works, there are fewer crushed rails caused by physical defects in the steel, the question of the wearing capacity of steel rails obviously becomes the all-important one."

Certainly the condition of the roadbed has much to do with rails breaking, crushing, and wearing. If the Pennsylvania and other railroads have done and are doing their part, Dr. Dudley courteously admits that the steel works have performed part of theirs. But as far as I am informed, the formulas which they have used have been and are still quite wide of the one he continues to recommend. The rails which are not breaking or crushing to so great an extent as formerly, contain higher percentages of both carbon and manganese.

I will venture the assertion that Dr. Dudley's road has put in but few rails during the last eighteen months that have not contained fully 0.35 per cent. of carbon and 1 per cent. of manganese. And probably the use of this formula will considerably antedate the time mentioned. These rails do not break or crush, because they were laid upon a better roadbed, were rolled from sounder ingots, were carefully hot-straightened, and, if I may be permitted a Hibernianism, were cold-straightened while still hot. But how will they wear? For an answer to that we must wait.

I have endeavored to study carefully Dr. Dudley's paper, but have failed to be convinced of the correctness of the conclusions which he draws from the chemical analyses and physical tests. I think I have no prejudice in this matter. The best formula for steel for rails is as earnestly desired by me as by any consumer of such steel. In my judgment averages in such investigations are exceedingly dangerous, unless made from an immense number of samples taken from metal that has had exactly the same history. By this I mean, the different samples ought to have been blown at about the same temperature, cast under the same conditions, heated alike, rolled at the same heat, and under the same reductions, hot and cold-finished alike, placed upon the same roadbed, and given the same amount and kind of wear. This is almost an impracticable proposition, but the failure to fulfil it can only be compensated by an immense number of other samples.

Some of us told Dr. Dudley before that his twenty-five samples were too few upon which to build up a theory, and it seems a little ungenerous to make the same charge against his present sixty-four; but I must do it. These sixty-four tests are not taken from rails which have been subjected to the same conditions; on the contrary, "sixteen of these rails were taken from level tangents and sixteen from level curves, eight from the high side and eight from the low side of the curves. Again, sixteen rails were taken from grade tangents and sixteen from grade curves, eight from the high side and eight from the low side of these curves." Asking for so great a number of tests means a tremendous amount of work and patience, but Dr. Dudley has taken up one of the most difficult problems, and must not be contented with a partial investigation. It took some of us a long time to learn how to make Bessemer steel at all; he must not expect to be able to so easily teach us how to make the best.

To illustrate why I object to his averages: I find among the

rails taken from a level tangent that the one which shows the least loss in section and the least wear per million tons of traffic had carbon, 0.423; phosphorus, 0.127; silicon, 0.083; manganese, 0.708; while another rail presenting within three of the worst results, had carbon, 0.428; phosphorus, 0.109; silicon, 0.038; manganese, 0.870. The next poorest had carbon, 0.452; phosphorus, 0.144; silicon, 0.037; and manganese, 0.708,—the manganese being exactly like the best. The poor steel had also very slightly the greatest density. The difference between 0.452 of carbon, and 0.423 and 0.428 could easily be caused by rolling one steel at a higher heat than the other. Again, on the low side of level curves I find the second best rail had carbon, 0.454; phosphorus, 0.145; silicon, 0.015; manganese, 0.726; while the poorest rail had carbon, 0.497; phosphorus, 0.136; silicon, 0.062; manganese, 0.724. I cannot now believe that the slight difference in the chemical constituents of these rails caused the great difference in their wear. If such is the case, then I for one stand appalled at the difficulties which surround the making of a perfect rail.

As before stated averages are dangerous. Dr. Dudley makes up a formula from the averages of his investigations, but admits that the silicon percentage is disturbed by an abnormal piece of steel No. 881. This had carbon, 0.483; phosphorus, 0.035; silicon, 0.480; manganese, 0.782; and stands eighth in sixteen tests. It may be remembered that in the discussion at the Baltimore meeting in February, 1879, I mentioned a rail then in the track of the Boston and Albany Railroad that contained carbon, 0.360; phosphorus, 0.124; silicon, 0.469; manganese, 0.571; and which had then been in the track five years. That rail is still in service and in good condition. Here we have two rails made by widely separated works, laid in the tracks of railroads hundreds of miles apart; one giving eleven years and one month of service and then not worn out, but on the contrary selected as a "slow-wearing rail;" the other one good after over seven years of wear. Will we take the average composition of these rails which did not break, nor crush, nor rapidly wear out, and assume that carbon, 0.420; phosphorus, 0.079; silicon, 0.474; and manganese, 0.676 is the proper formula for rail steel? If not, why not?

Dr. Dudley's averages of his 32 samples of good wearing rails gave him carbon, 0.334; phosphorus, 0.077; silicon, 0.060; manganese, 0.491. If that formula is right, stick to it. In fact such a one will be better for both the producer and consumer, than

the compromise which Dr. Dudley recommends. I think every steel-maker will bear me out in saying that sound steel can be more easily made under its provisions than with carbon from 0.25 to 0.35; phosphorus, 0.10; silicon, 0.04; manganese ranging from 0.30 to 0.40 aiming at 0.35. Theory is very fascinating, but in practice stubborn facts present themselves, and with steel containing 0.10 phosphorus, and not more than 0.35 manganese, the resulting ingots would be very unsound, and the rail mill would produce an indefinite number of imperfect rails, many of which would get into service in defiance of the most careful inspection; the result being crushed ends, flat places, and generally unsatisfactory rails. If low manganese is desired, the phosphorus must also be low; 0.10 per cent. cannot be so considered. In the 64 analyses there are but 16 with the manganese as low as 0.40 and under; and only 4 of these have the phosphorus above 0.085; 11 being under 0.07 and 6 under 0.05. The rails having less than 0.30 carbon, with the exception of 6, were made over 12 years ago, and of these 6, one was made 8 years, one 10 years, and four about 11 years ago.

At the time all of these rails, excepting one, were made, all steel was hammered, the blooming mill not having been invented. Under the hammer it is possible to coax steel into fair-appearing blooms, that would either go to pieces or roll very badly in the blooming mill. When the latter was introduced the steel makers had only at their command recarburizers poor in manganese and high in phosphorus. Moreover the American irons were then even much higher in phosphorus than our chemists told us. Hence a great deal of very poor steel was made. By poor I mean unsound steel. As high as 20 per cent. second quality or defective rails was a common run of work. While to-day with better irons, richer spiegels, and better melting furnaces, we rarely exceed 1 per cent., and run for days at less than one-half of that figure, and this on much more difficult sections than railroad engineers formerly required.

Just here let me ask Dr. Dudley whether he gave sufficient consideration to this very difference of section? Examples are presented by rails 902 and 903. The first stands at the head of rails from the high side of curve grade, and gave upon analysis: carbon, 0.322; phosphorus, 0.077; silicon, 0.026; manganese, 0.492. The second had carbon, 0.355; phosphorus, 0.108; silicon, 0.029; manganese, 0.490, and is at the foot of the list, with but 2 years 11 months service. The first had 7 years 11 months service, and was

of the old rounded head section, while the poor one, with almost the same chemical analysis, was of the square-head pattern.

If, as suggested by Dr. Dudley, even softer rails are desirable, there need not be any difficulty in filling such an order. I would be perfectly willing to contract to make rails containing not over, carbon, 0.15; phosphorus, 0.08; and manganese, 0.50. These rails would be perfectly homogeneous and stiffer than an iron rail of the same section, and ought therefore to hold up the load. The rail-makers both in this country and England are now making steel containing much more manganese than formerly. These rails are going out of the mills apparently better and sounder than those formerly made. Time only will demonstrate whether or not they are actually better.

The present Troy practice is to use irons containing the least phosphorus, to put in enough carbon to make strong steel, and enough manganese to make the steel roll sound, both while in the ingot and the bloom, to carefully heat the ingots and resulting blooms, hot-straighten the rails so as to leave the minimum of work for the cold press, which does its work while the steel is yet hot. And we have to be yet convinced by the wear of our rails that this practice is wrong. For our tests we cast a four-inch ingot from each blow; this is hammered into a $\frac{5}{8}$-inch bar, which when cold is required to bend to at least a U by the blows of a sledge, this bending being a much severer test than when done in a press. The steel is also quenched in water and tested for temper. Drillings are taken from the ingot and *accurate* carbon determinations made.

I prefer this plan to any test of the rail ends. To be perfectly conclusive, such tests would have to be made of both ends of the rail, and from every rail; for one end might be overheated, and the other not. Some blooms might be all right, and the rest of the heat spoilt. In a mill producing say 9000 rails per week, 18,000 rail-end tests would be no inconsiderable item, particularly if, as Dr. Dudley proposes, the test-piece, "12 inches long, $1\frac{1}{2}$ inch wide, $\frac{1}{2}$ inch thick," is to be slotted from the web of the rail. He would have to give a lease of the Altoona shops along with the rail contract.

Dr. Dudley's theory of infinitesimal teeth is interesting, and, if true, I should prefer having the teeth of my rack so strong that they would neither break off or flatten down.

As a matter of perhaps some interest, I present two pieces of Troy rails, cut off at the saws from two rails, not in the same heat, and

tested without knowing anything of their chemical composition. I had these pieces separately placed upon 10-inch bearings under a 7-gross ton hammer, a piece of 2½-inch round iron laid upon them as a fuller, and the hammer allowed to fall from 20 inches above the fuller, which, according to Haswell, gave a blow of 67.75 gross tons. The pieces were then turned over, the fuller placed upon the convex surface, and the hammer allowed to fall from 13 inches above the fuller, giving a blow of 58.45 gross tons. You will see that the rails do not show any signs of rupture, and their color at the points of torture prove them to have been absolutely cold when the test was made. I think these rails ought to be reasonably safe in the track. As you see by this piece of the head of one of these rails, I had it planed, and then some teeth cut in it by a cold chisel, and one-half of them pounded down with a hammer. The teeth of my rack did not break off. The analyses of these rails subsequently made are:

	I.	II.
Carbon,	0.410	0.880
Silicon,	0.050	0.058
Phosphorus,	0.086	0.082
Manganese,	0.942	0.840

In conclusion, I will say that Dr. Dudley's paper as a contribution to our knowledge of steel rails is valuable and interesting, but I protest against his conclusions being received as manufacturing or commercial axioms. From its being presented in the form of a report to the leading railroad of the country from one of its trusted officers, as well as from the tone of the concluding deductions, it is liable to be so received by railroad men. If any railroad company desires rails made under either of Dr. Dudley's formulas, and are willing to pay a price large enough to cover the loss in making them, well and good; but so long as the railmakers are compelled to *guarantee* the wear of their rails for a given number of years, justice requires that the composition of the steel from which these rails are made should be left to them.

WILLIAM SELLERS, PHILADELPHIA: The very interesting paper upon the wear of steel rails that has just been read presents the record of a series of investigations that are extremely valuable, and the deduction that has been drawn from the results noted seems to be unavoidable; the tests, however, to which it is proposed steel rails shall be subjected hereafter, with a view to determine their quality, should

have our careful attention, and with reference to these I desire to make a few suggestions.

While the manufacture of soft steel was yet in its infancy it was believed that the presence of phosphorus in any notable quantity was very deleterious, in fact fatal to the good quality of this product, and the greatest care was exercised to procure materials in which this element could not be more than traced. With the development of this art it has been found that larger and larger proportions of this hurtful ingredient may be used, providing always corresponding changes in the chemical composition shall be made to accord therewith.

It is perhaps beside the point to inquire whether the earlier belief was correct or not, the fact remains that steel is now produced which contains much larger proportions of phosphorus than would have been permitted a very few years ago, and that this steel is now considered to possess qualities which fit it admirably for use in rails; moreover it is well known that the degree of heat and the manipulation to which the ingot is subjected in transforming it into the finished product has an important influence in determining the characteristics that product will exhibit.

These facts have an important bearing upon the question, what shall be the tests which are to determine the quality we desire to attain. If the engineer is to specify the chemical composition and the mode or process of manufacture by which the manufacturer must work, it would seem that improvement in the art must to a certain extent be limited, and a vicious system would be introduced, injurious alike to the engineer and the manufacturer. The chemical composition has no value to the engineer, for no matter what the chemical composition, it is upon the physical qualities at last that he must rely to determine whether or not it will answer his purpose; it should be his business therefore to devise such physical tests as will determine absolutely whether or not the quality that he desires has been produced, while the manufacturer should be left free to make such chemical combinations or adopt such processes of manufacture as will fulfil the requirements of the engineer. It may, however, be questioned whether the physical data we now possess will enable us to agree upon the physical tests requisite to demonstrate the quality, but if this is admitted it only proves that further physical data are needed, for the quality is finally determined by use, the result of which our physical data should enable us to predict. Of these data the one most abundant is

the ultimate strength, and next to this ductility, bending, shearing, punching, torsion, impact, and fatigue, in all of which, except the last, abundant facts are at hand. As most specifications prescribe a high and a low limit for ultimate strength, it would seem to be the prevalent opinion among engineers that high or low steel, as it is technically termed, is to be determined by its ultimate strength, and it becomes important at this stage to define what quality it is that most accurately defines this term, that is to say, does it consist in high or low ultimate strength, or in high or low ductility relatively to its ultimate strength. It is essential for all structural uses that the engineer should know upon what ultimate strength he can rely, for upon this all his calculations must be based, but it is upon ductility that he must depend for safety, the measure of which he must determine; after which, the higher the ultimate strength he can obtain the better his material will be for any structural purpose; that is to say, with a given ductility the higher the ultimate strength of his material, the safer it is and conversely, with a given ultimate strength, the higher the ductility the safer it is. High ductility and high ultimate strength cannot be produced except with the most favorable conditions, both as to chemical composition and as to the mode of manufacture; the quality is therefore to be ascertained with most certainty by determining the relation of the one to the other, and for the same reason this relation would seem to be the factor which should most accurately define the term high or low, as applied to steel; and the requirements simply of an ultimate strength not less than ——— pounds per square inch, with a ductility not less than ——— per cent. would at once determine the character of steel required and the quality of it. It must not be understood, however, that the determination of this relation is the sole requisite in determining quality for every purpose, for the capacity to bear fatigue and shock is scarcely less important, as for example, the question now under consideration; and although it is probable that the material which exhibits high ultimate strength coupled with high ductility will prove to be capable of enduring the most fatigue and shock, we cannot affirm that there is any definite relation between the two, in fact we have many data tending to show that such a relation does not exist.

An examination of the data which Dr. Dudley has tabulated indicates that to establish the relation between ultimate strength and ductility alone would be insufficient to determine the wearing quality of rails, so that these data must be supplemented by some other; this

other, I suggest, should be that of fatigue from shock, not that of simply bending, which last Dr. Dudley "has found to bear a closer relation to the loss of metal per million tons than any of the other tests." I take exception to the classification of this test as one of the four ways in which a bending test could be applied. A rail bent under the drop test, and one bent in the testing machine by pressure slowly applied, would not be subjected to the same character of strains. While a drop test is a bending test it is also much more; the same number of degrees of deflection in the one case as in the other would, I think, represent very different powers of resistance in the material operated upon. With the same weight falling from the same height in properly constructed guides, the same *effect* must be produced with every blow. In fact it is difficult to conceive how any other form of test can produce more uniform effects or which can be more accurately measured; the *results* may be more diverse with such a test than with others because they are produced by pressure and shock, whereas nearly all other forms of testing produce their results by pressure alone. It is this difference, however, which commends the drop as the test above all others for rails as being more analogous to that by which the rail is tested in use, and we should be well satisfied that the objections urged against it are well founded before we abandon it for others which may appear to offer more uniform results. It may well be that uniform results obtained by a system of testing widely different from that we require our material to sustain in use, may have small value for determining in advance the effect of that use. I am thus driven to the conclusion that to obtain the relation of ductility to ultimate strength, together with the capacity to sustain fatigue from shock, would be to attain to absolute certainty as to the quality in an engineering sense.

There are, however, considerations other than that of the tests which must have attention before adopting a system of testing for steel rails, and as to these I would now make a few suggestions. The tests required to determine quality in the directions indicated are well understood, but simple as they are, the time that must be consumed in making them, would result in serious loss to the manufacturer if his mill is to be held for their determination; and if he proceeds with the execution of his order in advance he incurs a serious responsibility in assuming the risk of rejection for the large product that would be turned out before the requisite tests could be made. While the cost of a test for ultimate strength, ductility, and for capacity to bear fatigue would be small, the large number of such

tests that would be necessary to establish the quality of an ordinary order for steel rails would be a serious item, and as every item of cost must be eventually borne by the consumer it is important for the railway companies to adopt a regular system for testing their rails that shall not only be the most expeditious but the least expensive. For the purpose of inspection, therefore, it would seem to be sufficient to adopt a system that would be simply an indication as to the qualities desired, without subjecting the parties interested to the cost and delay which must result from exhaustive and thorough tests, and upon these indications the rails might be accepted. This would seem to accord with the best foreign practice, as illustrated by the very admirable paper upon "Rail Specifications and Rail Inspection in Europe," by C. P. Sandberg, C.E., read at the Lake Superior meeting, August, 1880. There are two tests which would give these indications with great accuracy, both of which could be applied without the expense and delay incident to preparation of specimens, and both of which require comparatively inexpensive machinery. These are the registering punch and the drop test. The former is a special tool which could be applied upon the crop ends and could be portable; the latter is too well known to require description, but its indications, if carefully noted would, I believe, be the most valuable of the two, but in conjunction with the punch they should be conclusive. The punching test would have this advantage, that by its use an inexpensive indication could be had of the quality of every rail. The suggestion that this test should be applied upon the fish-plate holes has probably prevented its introduction heretofore, first, because such holes are not now punched, and second, because to make such registration every manufacturer would have to procure a registering punch, and this would be difficult to apply upon existing machines. If this tool should be recognized as a part of the inspector's outfit and specially adapted to his needs, it might soon come into general use if care was used to maintain the punches and dies in good condition.

In conclusion, I suggest that if the physical tests are to be supplemented by chemical analysis the specification for this analysis should not be complete; that is to say, in place of giving the proportions of carbon, phosphorus, silicon, and manganese, a maximum limit should be fixed respectively for phosphorus, silicon, and manganese only, leaving the carbon to be varied by the manufacturer, so that he may properly be required to furnish material that will fulfil the physical conditions; for it is evident that if the engineer defines the chemical

composition, he cannot reasonably ask the manufacturer to guarantee that this composition shall give certain physical results.

W. R. JONES, PITTSBURGH, PA.: The question that naturally occurs to me is this: Has Dr. Dudley in his investigations been aiming to prove a theory, or has he been guided by an earnest desire to discover what are the proper elements in the composition of a good-wearing steel rail?

Unfortunately, for correct chemical information, he has omitted in his analyses two very important elements,—sulphur and copper. Now, before we will even begin to admit the correctness of Dr. Dudley's conclusions and the formula he prescribes, we will at the start question the propriety of any chemist or scientist prescribing a formula for making steel when he has ignored such important elements as sulphur and copper. I, for one, will not accept any such formula.

Are we sure, or is Dr. Dudley sure, that the chemical analyses embodied in his paper are correct? This may seem a presumptuous question, yet, with my experience with chemists, I naturally doubt the correctness of the analyses, and, before I will accept them as correct, I will ask that comparative tests of phosphorus and manganese be made by the Pennsylvania Railroad chemists and the chemists of the leading steel-works in the country. Let us first verify the correctness of the analyses before we consider the conclusions. I can enumerate a great number of instances in which chemists have differed very widely in their determinations of phosphorus and manganese. A prominent iron firm made a contract with the Edgar Thomson Steel Company to deliver pig metal guaranteed to be between 0.07 and 0.08 phosphorus; an analysis by our chemist resulted in phosphorus 0.148 and 0.152,—a rather startling difference! Again, a sample bar of steel, in which our chemist reported phosphorus 0.11, was tested by a chemist of another Bessemer works, and his determinations were phosphorus between 0.07 and 0.08. A leading engineering establishment of Pittsburgh bought iron claimed by a chemical analysis to contain 0.08 phosphorus; our Mr. Ford found phosphorus 0.145. A chemist connected with an open-hearth works reported manganese in a piece of steel, 1.14; in a second determination from the same piece of steel, by the same chemist, manganese was reported 0.43. The chemist was kept in ignorance of the fact that both samples were from the same piece of steel. Two determinations for manganese

were made by the same chemist from a piece of steel; he reported manganese 0.61 and 0.58. Our chemist, in the same steel, reported manganese 0.324 and 0.303. I could give innumerable instances of the wide difference in chemists' determinations of phosphorus and manganese. I think I have cited sufficient cases to sustain the position I have assumed, viz., that before the determinations made by Dr. Dudley's assistants are accepted as being correct they should be verified by chemists of greater experience.

I find on a close examination of the doctor's paper that he has taken no notice whatever of the increased weight of cars, increased weight of locomotives, with increased speed, in his tonnage calculations. Now, there is a vast difference between the tonnage of 10 to 12 tons in an ordinary freight car with eight wheels passing over rails at a moderate speed, and 15 to 20 tons on the same number of wheels at an increased speed. Since 1874 the Pennsylvania Railroad Company has been steadily increasing the weight of both engines and cars. The duty to which rails are now subjected I believe is fully 60 per cent. greater than that before the year 1874. On looking over the paper, we find a number of rails, classed as good-wearing rails, that have for years been subjected to comparatively light tonnage on a wheel-tonnage basis, compared with a great number of rails classed as fast-wearing rails, which in some cases I find have had passing over them nearly twice the number of tons per month, and all on heavier wheel tonnage.

As an illustration I cite rail No. 937, with the following analysis: carbon, 0.454; silicon, 0.015; phosphorus, 0.145; manganese, 0.726; with only 2 per cent. elongation. In accordance with the deductions and formula this should be a very bad rail, yet on close examination I find that this rail has been subjected to a monthly tonnage of 747,628 tons. If we examine the rail No. 929, which was laid within two miles of rail 937, we find: carbon, 0.235; silicon, 0.080; phosphorus, 0.055; manganese, 0.300; elongation, 24 per cent. This rail was subjected to a monthly tonnage of only 381,235 tons, while rail No. 937 was subjected to 96 per cent. more monthly tonnage, and yet rail No. 929 is classed as a good rail. If we assume that 50 per cent. more loaded cars pass east to Philadelphia than pass west from Philadelphia, we find the wheel tonnage assumes a very important aspect in determining the wearing qualities of rails. Again, the bad rail was in the track forty months, and only shows a wear of $\frac{5}{100}$ of an inch in vertical section, and has

been in the track since the advent of heavier engines and heavier cars; while rail No. 929 has had the advantage of at least seven years of comparatively light traffic on light wheel tonnage. The question which of these two rails has been subjected to the greatest amount of wheel tonnage I leave to some one to calculate who has more time to devote to this subject than I have.

In regard to the method proposed by Dr. Dudley to test the rails at the works, I can only say I much prefer the methods suggested by Mr. Sandberg, in his paper read before the Institute at the Lake Superior meeting, with this slight modification, viz.: I would subject a 50 and 52-pound rail to a drop-test of 1800 pounds, falling a distance of 14 feet on the rail, on supports 3 feet apart; for a 54 to 56-pound rail, 16 feet drop; for a 56 to 58-pound rail, 18 feet drop; for a 58 to 60-pound rail, 20 feet drop; and so on in the same ratio. I would also adhere to the test-bar, drawn out from the head of the rail down to 1 inch square, then placed under a steam-hammer and bent through an angle of 110°, the distance between centres of supports of the bar to be from 10 to 12 inches. Dr. Dudley may think these tests crude; I believe them to be simple, thorough, effective, and reliable, and in this I fully concur in the views of Mr. Sandberg.

If Dr. Dudley and the Pennsylvania Railroad authorities believe their deductions are correct, let them have rails made in accordance with the doctor's first formula,—phosphorus, 0.077, carbon, 0.334, silicon, 0.060, manganese, 0.491,—and add to it, the less sulphur and copper the better, and, as a matter of course, pay the difference in price involved in the difference in the price of metals; but when Dr. Dudley attempts to formulate a rule to govern the steelmakers, based on his knowledge, I, for one, decidedly object; and I frankly tell him that he is opposing all the researches and investigations of the best chemists and metallurgists, both here and abroad.

I have serious and grave doubts if steel made in accordance with his second formula would give a good record in the track. I experimented on this formula in attempting to fill an order. Mr. Sandberg in his paper refers to the filling of an order of 2500 tons on the same formula, and my experience was the same as his. The ingot was a conglomerate mass of honeycombs. It made bad blooms, and I do not believe it made good rails. The rails are now in the tracks of the West Pennsylvania road, and if they do prove to be good rails, I shall be very much surprised.

WILLIAM METCALF, PITTSBURGH, PA.: In rising to discuss Dr. Dudley's paper, I feel somewhat as I did at the Baltimore meeting —that a "crucible" man has no right to interfere in a "Bessemer" discussion; yet having read the paper very carefully, I feel impelled to say something, for two reasons: First, because I believe Dr. Dudley is entirely on the right track, and having undertaken and partly accomplished a great work, he is entitled to the help of all who have experience in these matters; and second, because the data given force me to concur in Captain Jones's opinion that the analyses are incomplete, since they ignore sulphur, copper, nitrogen, and possibly other injurious elements.

In an experience of fourteen years, and with probably more than a hundred tests, we have never found the chemistry and the physics of crucible steel to disagree. If in any case a disagreement has appeared, it has been our invariable custom to go over all our physical tests with great care, and if we found no error, then to refer the matter back to the chemist, who has invariably found some unexpected element to account for the trouble.

It is only just to the chemist to say here, that ordinarily he is only expected to determine phosphorus, silicon, sulphur. Generally the metals, with the exception of manganese, are not looked for, although a watch is usually kept for copper and arsenic. Further, in most cases we have found our own work more liable to be faulty than the chemist's.

Having arrived then at such a degree of experience that we can predict the analysis from our tests, or our tests from the analysis, with almost absolute certainty, I can see no reason why the same results may not be attained in the Bessemer practice. But two things are essential, neither of which we have here; first, complete analyses; and second, a record of the nature of the blow, the heat at which the ingots were bloomed, and the rails finished,—in short, a complete history of the manufacture.

This latter is quite as essential as accurate and complete analyses. Dr. Dudley ignores sulphur and copper on fair enough grounds commercially speaking, but when he announces so grave a conclusion as he has reached, in a scientific way, the omission of any elements that may affect the conclusion is hardly justifiable. His differences of phosphorus units, which I must term units of rottenness as far as phosphorus is concerned, and which I am sorry he did not name *units of alloys*,—are very small, and if sulphur and copper had been included they might have upset his conclusions altogether. The

omission of nitrogen is not to be criticised in the same way, becau it has not been usual to regard nitrogen in testing steels, yet I am forced to believe that nitrogen plays a very important part in Bessemer steel.

We had occasion recently to test some of the finest Bessemer st that is made, in order to ascertain how far the Bessemer people w encroaching on the domain of the crucible steel manufacturers. I the accompanying table are the analyses of the Bessemer steel s ferred to, two samples of the very best foreign crucible steel, s one of the best American crucible steel.

Kinds of steel.	Carbon.	Phosphorus.	Silicon.	Sulphur.	Manganese.	Co
Bessemer	0.400	0.027	0.008	trace.	.....	—
Foreign crucible	1.295	0.020	0.009	trace.	0.050	
	0.862	0.005	0.007	none.		
American crucible	0.960	0.021	0.033	trace.	0.077	

All three of the crucible steels were of exceptionally good qu It will be observed that according to the analysis, the Bessemer should have been equally good. Upon a careful test of an 0.80 bon billet it proved to be thoroughly worthless.

The case was then referred to Professor Langley, and he attrib the trouble to oxygen, and predicted that if we would melt a carbon billet with a little ferromanganese to remove the oxygen bring up the carbon to 0.80, and also give a little more silicon w the steel would take from the crucible, that we would have a equal to the others given above. To be sure of our work, we m the billet, the analysis of which is given above, and produce ingot of about 0.80 carbon, as near as the eye could determine, that is within .03 in such high steels. The remelted Bessemer was just as bad as the other, and of this we assured ourselves b most careful and repeated tests.

Now we know oxygen was not the cause of the fault, for if it been, the ferromanganese would have removed it. In the Bess manufacture immense volumes of nitrogen are blown through molten mass, and by the evidence of all of the most em chemists who have examined the subject, we know that nitr does unite with iron, that the compound is brilliantly lust hard, brittle, and even friable, and that it will harden like s We also know that there is a peculiar lustre in all Bessemer s which makes it easily distinguishable by an expert from crucib

open-hearth steel, provided none of them have been overheated. Is it not more than probable, then, that nitrogen is entitled to far more serious attention than it has yet received?

Dr. Dudley classes carbon with phosphorus, silicon, and manganese in making up his units, and he may be correct in his make-up in the relative values of each, but I cannot see how he has proved his formula, nor how it is to be disproved with our present knowledge.

While maintaining that carbon in steel is the great friend of the manufacturer and the only fit alloy of iron, I must admit that when it is present in quantity with phosphorus, silicon, manganese, or sulphur in quantity, it vitalizes and makes more active all of the bad qualities of these elements, and therefore if Dr. Dudley must have the quantities of these elements in his rails which he permits in his formula, he is quite right in saying that the softest rails ought to wear the best. In regard to the wearing of wire dies we have found

Carbon	Tungsten.
1.37.	0.78.

too soft, *i. e.*, it wore too easily. Also steel of the composition

Carbon,	Silicon,	Sulphur,	Manganese,	Phosphorus,
1.7	0 20	0 091	0.387	0.02

was too soft. The best foreign dies contained

Carbon,	Silicon,	Sulphur,	Manganese,	Phosphorus,
2.89	0.14	0.031	0.26	0.02

and equally good and entirely satisfactory homemade steel contained

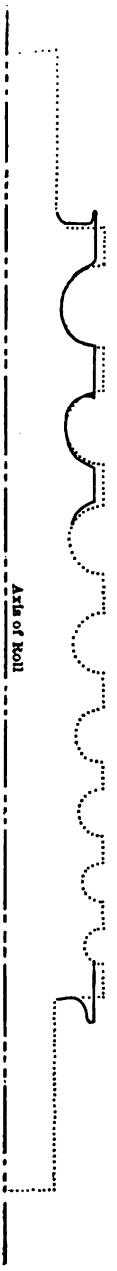
Carbon,	Silicon,	Sulphur,	Manganese,	Phosphorus,
2.37	0.20	0.091	0.18	0.03

In this case good wear depends upon high carbon.

In steel rolls, in which we have had some experience, we have found that very soft rolls of about 0.30 carbon wore too fast from excessive flow, taking the shape shown in the cut (page 550), the overflow sometimes amounting to more than half an inch. This cuts away the brasses and involves much redressing. Rolls of about 0.70 carbon made from the same iron, neither flow nor crack to any serious extent, and will do two to three times as much work as the softer rolls.

We know that steel flows under pressure, that the milder the steel the easier it will flow, and the easier it will shear; yet in the paper under discussion flow is disregarded entirely, although there is plain evidence of it in many of the sections given. Low shearing stress is

advised as conducive to high wear, while it would seem plain that chilled flanges must act as admirable shears to trim off "flowed" edges.



Dr. Dudley says low phosphorus units ought to give the best wear, and so they ought. He proceeds to prove it by grouping the 32 rails of least wear, and the 32 rails of most wear in two groups, and taking a mean of their analyses. By a happy accident this mean sustains his view, or perhaps it would be fairer to say, from this accident he draws his conclusions. These groups consist of all sorts of rails, of different make, different conditions of wear and different tonnages. Would it not be fairer to compare rails from the same part of the track, subjected to the same conditions of wear, of the same tonnage, and presumably of the same make? Arranging the 64 rails under consideration in this way by means of the history given, I find 30 groups consisting of twos, threes, and fours. Comparing the phosphorus units and wear per million tons as given in the table, I find that in twelve groups the softer rails have shown the least wear, while in eighteen groups the harder rails have shown the least wear.

This gives 18 against Dr. Dudley to 12 for him, and it seems as if this mode of comparison were the fairer, if the presumption is correct, that the rails of these different groups were of the same make in each group, because in such case the chances are that the physical conditions due to modes of manipulation in manufacture were more nearly the same than they could possibly be in the more general average given in the table.

I would like to ask Dr. Dudley to relieve us, if he can, of a term which he has introduced into his paper and specifications, and which, for the sake of harmony, ought, I think, to be obliterated. I refer to the word "hardener." This is a term properly applied to any substance contained in steel, for anything mixed with iron will make it harder. But carbon is the great "hardener," and produces all of the wonderful and useful properties in steel with which we are familiar, and of the nature of which we know so little. Carbon, then, ought to be distinguished as *the* hardener, and all other com-

ponents should be known by some other name. If not, we shall have quack steelmakers coming out with more silicon steel, phosphorus steel, sulphur steel, and the like. And why not? Are they not all hardeners, and is any one better than another.

This is a serious matter, for we have too much duplication of meanings now. For instance, if you go to a founder and ask if he has a chill to make a certain size of die or roll, he asks, in reply, how much chill you want, and you tell him, say, half an inch or an inch, as the case may be. Then he asks if you want a tough chill, or a mild chill, or a hard chill. Would not an outsider be utterly puzzled to know what a chill was?

Again a steelmaker talks of temper, and refers to steel of 0.30, 0.40, or 1.00 carbon, as it may happen; and a steel-user talks of temper, and means a yellow, or brown, or blue color, left on the steel after it is tempered. I once travelled many hundreds of miles to see about a steel trouble. A buyer had sent back a shear-knife which would not cut. Not waiting till the knife was received, I started off, and asked my partner to telegraph me his opinion after he had received the blade. We were both sure it had been burned. After my arrival on the scene and finding a man in real trouble, and a great temper, a message came in these words, "Temper too high; will send another bar." Greatly pleased, and thinking my way plain, in an evil moment I showed the message to my troubled friend, who interpreted it to mean that he had improperly treated the steel; and the indignation created was as profound as it was unexpected.

Who, then, can define steel? An International Committee of this Institute and many others have wrestled with the question, and yet to-day there is a heavy suit pending in the United States courts, turning upon the question whether steel is steel or iron.

Now we are threatened with the war of the "hardeners," and the contemplation of another complication in our nomenclature is no joke for the steelmakers; and in their behalf I appeal to Dr. Dudley to relieve us before it is too late.

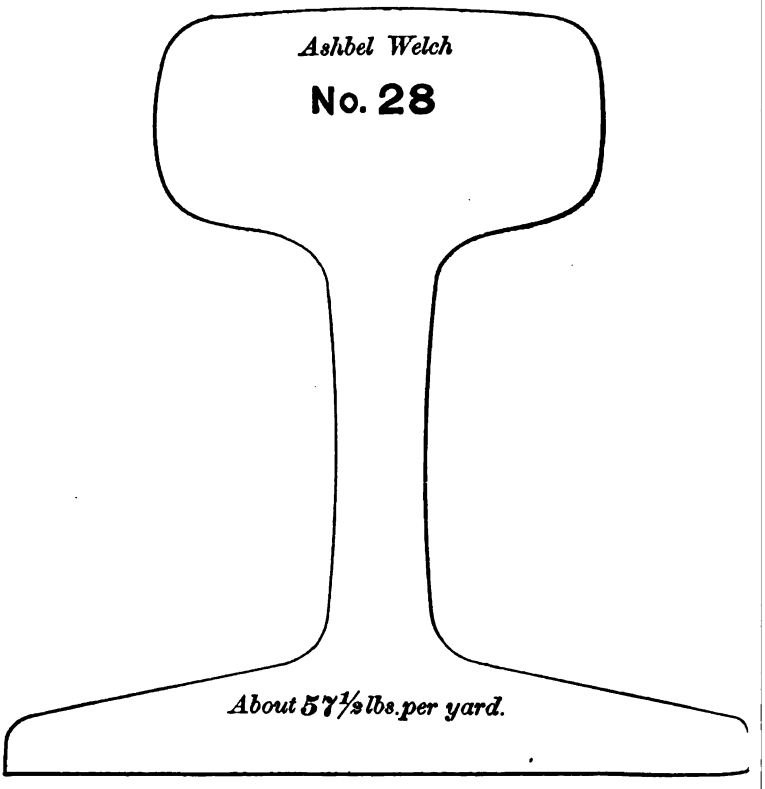
In conclusion, allow me to say that I hope my remarks will not be regarded as antagonistic to Dr. Dudley's great work, for I could have no possible reason for entering the lists as an antagonist; on the contrary, I decidedly agree with him that the chemistry of steel is an important factor in its manufacture, and chemistry and physics must go together if results of any value are to be reached; and I firmly believe that eventually all engineers will know how

to make and to appreciate chemical specifications. I therefore feel that we should all contribute all we know or think on the subject, and I hope these remarks will be considered a thoroughly sympathetic criticism.

LETTER FROM WILLIAM R. HART.

I was this morning an interested listener to the remarks of Mr. Ashbel Welch in regard to his designing a new section for steel rails, in 1866; and for the sake of the truth of history, and in order to give the credit to an American (and where it rightfully belongs) of designing the first section for steel rails, which was intelligently adapted to that material, I beg to state the following facts:

On the 14th of August, 1866, Mr. Ashbel Welch gave me an order for 200 tons of steel rails, to be made for the Camden and Amboy Railroad, from a section designed by him. A copy of this section I append herewith.



Messrs. John Brown & Co., of Sheffield, for whom we were then agents, at first declined to roll these rails, owing to the thinness of the flange, but subsequently accepted this order. In principle, as I think you will see from the section, this pattern was similar to what is now known as the Sandberg section, having a large amount of metal in the head, and without superfluous weight in the stem and base. This section was put upon our book, with the title "Ashbel Welch section;" and this name was also rolled upon the stem of the rails. We sold afterward large quantities of these rails under this title to the Philadelphia and Baltimore Railroad Company, as well as to the Camden and Amboy Railroad Company.

I make this statement in justice to Mr. Welch, who ought to have the credit of designing a section which had much to do with making steel rails a success. At the time Mr. Welch designed this section it was quite a new departure, and as our old section-book shows it was very different from any of the sections which up to that time had been ordered by any of the railroad companies.

I shall be very glad if this fact can be recorded upon the minutes of the Institute, and remain,

Yours very truly,

WILLIAM R. HART,

PHILADELPHIA, February 17th, 1881. *Agent, Naylor & Co.*

LETTER FROM R. H. SAYRE, BETHLEHEM, PA.

. . . . The subject is one of great interest in every point of view to railroad managers and steel-rail makers. It has occurred to me that if in this connection your society would take up the matter of the shape or section of steel rails and the form of joint, and be able to arrive at such form for different weight of rails as you could recommend to the railroads of this country with a view of obtaining uniformity, it would be, in case of adoption, of great value both to the railroads and makers of rails.

My idea is that if both your society and that of the civil engineers should join in the adoption of templates and their recommendation, it would be more likely to have the desired effect.

Yours truly,

ROBERT H. SAYRE.

WILLIAM KENT, PITTSBURGH, PA.: The steel manufacturers of this country must ever be grateful to Dr. Dudley for his painstaking and conscientious endeavor to establish the relation between the chemical analysis and the wearing capacity of steel rails. They must thank him for the vast array of facts he presents, and especially for having given them sixty-four analyses with which to combat his own conclusions and to establish their own, which are entirely opposite to his.

In Dr. Dudley's discussion of his former investigation, at the Pittsburgh meeting, he said, "If you do not like my conclusions, draw your own conclusions." I have studied his last paper as thoroughly as the limited time since I received it would admit, and have drawn some conclusions which I will first state, and then attempt to demonstrate.

Briefly stated, my conclusions are: 1st, That as far as these 64 analyses reveal anything of service to railmakers and consumers, it is that within the following chemical and physical limits, viz.,

Carbon,	0.20 to 0.60
Phosphorus,	0.026 to 0.145
Silicon,	0.015 to 0.480
Manganese,	0.252 to 0.880
Phosphorus units,	20.3 to 5.72
Bending weight,	2270 lbs. to 4260 lbs.
Deflection,	18° to 190°

or in other words within the limits of nearly the whole range of the chemical and bending tests of these 64 rails, the wearing capacity bears no relation at all to carbon, to phosphorus, to silicon, to manganese, to phosphorus units, to bending weight or to deflection; or if there is any relation between the wearing capacity and these six or seven variables, it is so obscured by the action of other causes or variables not yet known, that such relation cannot be expressed by any practical formula.

2d. That the difference in wearing capacity of these 64 rails was not due to carbon, to phosphorus, to silicon, to manganese, or to any combination of these four elements, but that it was due to some other cause or combination of causes, of which Dr. Dudley's whole investigation furnishes us no clue whatever. A few of the many possible causes I may name: sulphur, copper, oxide of iron, inclosed air or other gases, overblowing, underblowing, overheating, underheating, too hot-finishing, too cold-finishing, cold-straightening, too great or too little reduction from the rail to the ingot, or the portion

of the ingot from which the rail was taken, as top or bottom. I have no idea which of these causes has the greatest influence in determining the wearing capacity of a rail,—probably no one else has,—but I firmly believe that some one or more of them has far more influence than all the four chemical elements named in Dr. Dudley's analyses within the limits which I have mentioned.

3d. That the railroad companies must utterly abandon, for the next ten years at least, the attempt to limit rail manufacturers to a certain prescribed chemical composition, unless within the wide range of composition I have given above. If they would seek to establish a definite specification by which to insure good wearing capacity, and at the same time not make the specification an impracticable one for railmakers to meet, as Dr. Dudley's certainly is, they must inaugurate another investigation (and I know of no one so well fitted to undertake it as Dr. Dudley himself, after he shall have thoroughly disabused his mind of conclusions already formed), which investigation shall take at least ten years to complete, and shall include not only the effect of the four chemical elements now under discussion, but all the other supposed causes of differences in wearing capacity which I have mentioned above, besides many others I have not even thought of. Such an investigation I believe the railmakers would not object to; they should rather contribute towards it. It would richly repay the railroad companies by enabling them to secure better rails, providing that after the investigation was concluded it should reveal the causes of defective wearing capacity, which Dr. Dudley's present investigation does not do.

4th. That Dr. Dudley's failure to establish, after years of careful investigation, the relation between the chemical analysis and the wearing capacity of a rail, should be a lesson to other consumers of steel besides the railroad companies, not to attempt to regulate the steel manufacture by a chemical specification based upon their own investigations, far less elaborate than that of Dr. Dudley or that of the manufacturers. It is a common occurrence for a steel manufacturer to be asked to guarantee both a chemical and a physical specification entirely inconsistent with each other, and one or both impossible of fulfilment. The attempt to fill orders with such specifications is not only annoying but often even ruinous to the manufacturer, causing the rejection of much steel that is even better adapted to the wants of the consumer than some of the steel which is accepted. This is precisely the result which would happen if Dr. Dudley's rail specifications were to be insisted on.

I will now undertake to give a reason for the conclusions I have drawn. Suppose that the Pennsylvania Railroad Company were at once to insist that all rails furnished them should conform to Dr. Dudley's specifications in these six particulars:

Carbon,	.25 to .35
Phosphorus,	not over .10
Silicon,	not over .04
Manganese,	.30 to .40
Bending weight,	not over 3000 lb.
Deflection,	not under 130°

Suppose that before the rail manufacturers had "got the hang" of making rails within these rigid limits, and while they were yet making them with the wide range of composition which they are now doing, I should be sent as inspector to one or more works to inspect 64 lots of rails, one rail being taken out of each lot for test, the test rail being supposed to represent exactly the lot from which it was taken. Suppose, further, that I test these 64 rails chemically and physically, and find that the results are exactly those given in Dr. Dudley's tables. I tabulate the results as I have done here, rejecting all the tension and torsion tests, as these are not included in my instructions, and I carefully examine the table to see how many lots I should accept and how many I should reject. How many of these 64 rails or lots would I have to accept under these specifications? *Only three!* And one of these three would be classed by Dr. Dudley as a bad rail, standing number 10 out of the 16 rails marked "level tangent."

I would reject *sixty-one* of these sixty-four rails (or lots), for violation of from one to all six of the specifications.

34	for	too great bending load.
29	"	small deflection.
42	"	high or too low carbon.
31	"	high phosphorus.
32	"	high silicon.
52	"	high or too low manganese.

As Dr. Dudley classes the 64 rails into two grand divisions, viz., 32 slower wearing and 32 faster wearing (I call them here good rails and bad rails for the sake of brevity), I have to reject 30 of his *good rails.*

18	for	too great bending load.
7	"	small deflection.
21	"	high or too low carbon.
11	"	high phosphorus.
14	"	high silicon.
21	"	high or too low manganese.

On the tables (Plates 6 and 7) of Dr. Dudley's paper I have indicated each cause of rejection with a black mark. You will notice that the tables are nearly covered with black marks, that their position follows no regular law, but seem to be distributed with entire impartiality. I count the black marks, and find the total causes of rejection to number 210 out of a possible 366, or an average of 3.44 for each of the 61 rails rejected. Of the 31 bad rails rejected, the black marks or causes of rejection number 123, an average of 3.97. Of the 30 good rails rejected, the causes number 87, an average of 2.9. Here is a point in favor of Dr. Dudley, the 31 bad rails rejected do have a worse chemical and physical record than the 30 good rails rejected, the average number of black marks against the bad rails being greater in the ratio of 3.97 to 2.9. But his gratification in this regard must be somewhat diminished when he learns that by selecting a number of very, *very* bad rails, which I have done on the tables, drawing heavy lines around them and marking them *worst rails*, viz., the 2 worst rails out of 16 marked tangent grade, the 4 worst rails out of 8 marked curve grade, low side, the 3 worst out of 8 curve grade, high side, the 3 worst out of 16 level tangent, the 2 worst out of 8 level curve, low side, and the 4 worst out of 8 level curve, high side, the total causes of rejection of these 18 rails is 68, or an average of only 3.78.* That is, the 18 worst rails have fewer average causes of rejection than the whole 31 rejected rails designated "faster wearing," in the ratio of 3.78 to 3.97.

In Dr. Dudley's table of averages he compares the chemical and physical properties of 32 slower-wearing rails with those of 32 faster-wearing rails in all conditions of service. The comparison agrees with his conclusion except in the matter of silicon, the average silicon of the bad rails being lower than that of the good rails. Let us carry the comparison a little further, and compare the properties of the 18 worst rails, which I call very, very bad rails, with those of Dr. Dudley's 32 bad rails, and see whether it strengthens his position. Here is the comparison:

	Loss per million tons.	Bending weight.	Deflection.	C.	P.	Si.	Mn.	Phos. units.
32 good rails,	.0506	2878	160°	.334	.077	.060	.491	31.3
32 bad rails,	.1028	3222	133°	.390	.106	.047	.647	38 9
18 worst rails,	.1326	3209	135°	.412	.109	.040	.677	40.4
13 bad (?) rails,	.0668	3267	136°	.369	.105	.050	.632	37.9

* The method of selection of these 18 rails is not an arbitrary one, as will be seen further on. Of the 16 level tangent rails, 13 should be classed as good and 8 as bad; a fairer classification than that of 8 faster and 8 slower wearing.

The 18 worst rails show a greater loss per million tons than the 32 bad rails by 29 per cent., while in three elements of Dr. Dudley's specifications, viz., bending weight, deflection, and silicon, they are slightly better, according to his ideas, and in three others, viz., carbon, phosphorus, and manganese, slightly worse. If Dr. Dudley's conclusions were correct we should expect to find that a lot of rails having 29 per cent. worse-wearing capacity than a larger lot which included them, would show a very marked deviation in average analysis and bending tests from the average analysis and bending tests of the larger lot; but actually the deviation is so slight that Dr. Dudley himself could not tell, if the results of tests alone were presented to him, which lot had the greater and which the less wearing capacity.

But I have carried the comparison still further. In the fourth line in the table I have placed the record of the other 13 bad (?) rails, out of the 31 faster-wearing rails, which would have been rejected under Dr. Dudley's specifications. (I have omitted in this average, rail No. 920, classed by Dr. Dudley as a bad rail from its faster wearing, but which conforms to his specifications in every respect.) I have placed an "(?)" after the word bad in designating these rails, as I think they should have been classed with the 32 good rails, on account of their wearing capacity being much nearer to that of the good rails than to that of the 18 worst rails with which they are associated. Comparing the 18 worst rails with the 13 bad (?) rails, we find the former to be over 98 per cent. (or nearly double) worse in wearing capacity than the former, while their analyses and bending tests indicate them to be very nearly alike. The worst rails are lower in bending weight and silicon, and only slightly lower in deflection, and slightly higher in carbon, phosphorus, and manganese. Here is a very plain case selected from Dr. Dudley's own work. Two distinct lots of rails, one lot twice as good in wearing capacity as another, but both lots closely agreeing in average analysis and bending tests. What stronger evidence could be produced of the fallacy of his formula?

If, in any large series of observations of the values of different variable quantities, such as are here dealt with, there exists any law of interdependence of such variables, the figures representing such observations can be plotted on cross-section paper, and the law will be plainly revealed by a curve or straight line drawn through the various observations. I have thus plotted the results of Dr. Dudley, and have made 42 curves, or attempts at curves, to discover, if pos-

sible, the existence of any law of interdependence of the variable wearing capacity in the six series of rails, viz., tangent grade, curve grade high side, curve grade low side, tangent level, level curve, high side and level curve, low side, with the seven other variables, bending weight, deflection, carbon, silicon, phosphorus, manganese, and phosphorus units. Here is the diagram (Plate I) with the forty-two attempts to form as many curves. You will see there is neither curve nor straight line here,—nothing but a heterogeneous mass of ups and downs and straights across,—not the slightest indication of any law in any single curve which is not contradicted by another curve of the same variable in another series.

This set of curves, or rather zigzags, shows plainly my reason for separating Dr. Dudley's 32 bad rails into two series, one of 18 worst rails, the other of 14 which nearly approach the good rails. In the curves of the tangent grade rails, the two worst rails, 882 and 893, in their plotted positions in the curve remove themselves far from the main body of these rails, and therefore in contrast with the others they are justly named the very, very bad rails of this lot. This grouping of the very bad rails far away from the better rails is still more plainly seen in the level tangent rails, where 13 rails are comparatively near together in position, and the other 3 are far removed from them, thus plainly indicating that if we wish to consider the relation of the chemical composition of these 16 rails to their wearing capacity, the method of averaging the 8 faster wearing and the 8 slower wearing—which Dr. Dudley seems to think is the only good one—is not the best by any means, but that to obtain an intelligent deduction the thirteen fairly good rails must be contrasted with the three rails which are widely different from them in wearing capacity.

I have said that these zigzags indicate the absence of any law of relation between wearing capacity and the six variable quantities under consideration. I am surprised that Dr. Dudley did not include his phosphorus units in his specification, as I regard this idea of phosphorus units as a most valuable conception, and one likely to lead to the advancement of our knowledge of the relation of the physical to the chemical qualities of steel. For this reason I have included phosphorus units in my plate of zigzags, although Dr. Dudley has not named it in his specifications. I thought it probable that by plotting the phosphorus units, I might possibly discover whether they had any relation to wearing capacity, although carbon, phosphorus, silicon, and manganese had no such relation. I discovered none. But there is a very marked peculiarity in the zigzags repre-

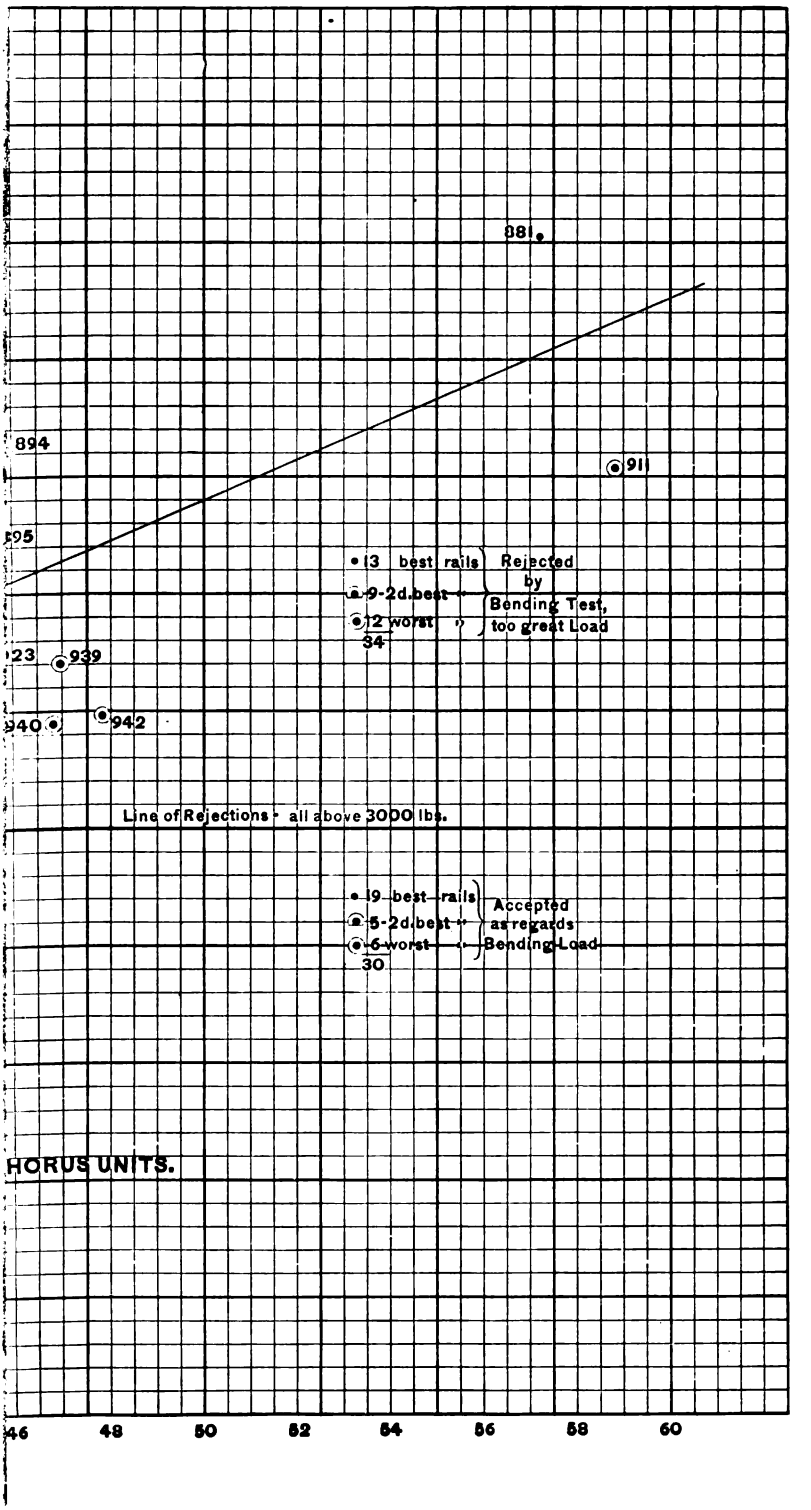
senting phosphorus units besides that of general relation to the four chemical elements which follow as a matter of necessity, namely, the almost entire parallelism of the lines of phosphorus units and bending weight. This suggests at once the existence of a relation between phosphorus units and bending weight, and I have, therefore, made another diagram, plotting the figures expressing this relation. The accompanying Plate II shows bending weight at the side of the section paper, and phosphorus units at the bottom. You will plainly notice that there is an evident trend of the dots representing the rails in the direction of an ascending inclined straight line. The whole range of bending weights being 2000 pounds, the deviation of the position of any rail from this inclined straight line (with only two exceptions) is an ordinate representing less than 450 pounds. The inclined straight line is the average direction of trend of these dots, and the individual dots do not deviate greatly from this average direction. The law of the relation between phosphorus units and bending weight is thus clearly established, and it is this: *The increase of bending weight is directly proportional to the increase of phosphorus units.* The discovery of the law is a strong presumptive proof of the correctness of Dr. Dudley's hypothesis in regard to the hardening influence of the four chemical elements upon steel, viz., that the relations of phosphorus, silicon, carbon, and manganese are to each other in respect to hardening as the numbers, 1, $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{1}{4}$. Dr. Dudley is certainly to be congratulated upon this discovery or presumptive proof of his hypothesis.

The fact of the law of relation of bending weight to phosphorus units being so plainly indicated in these 64 analyses and tests, while there is no such indication from these tests of any similar relation existing between wearing capacity and phosphorus units, or between wearing capacity and carbon, phosphorus, silicon, manganese, bending weight, or deflection, is almost absolute proof in itself that such relation does not exist at all, or, as stated in the first part of my remarks, if it does exist it is entirely obscured by the influence of other variable quantities not considered in Dr. Dudley's paper.

On the diagram on which is plotted the relation of phosphorus units to bending weight I have indicated the position of each of Dr. Dudley's 32 slower-wearing rails by a single dot. The 18 worst rails of the 64 are indicated by a dot surrounded by a circle, and the remaining 14, called second-best on the diagram, are indicated by a dot surrounded by a semicircle. By drawing the line between rails which would be rejected on Dr. Dudley's specification for bending

146
48
50
52
54
56
58
60

Kent.—Plate II.



weight alone, viz., not above 3000 pounds, and counting those above the line, it is seen that there are 34 rails rejected out of the 64, and of these 34, 13 are the best rails of the series (Dr. Dudley's slower-wearing rails), 9 are the second-best rails,—almost as good as the former,—and 12 are from the 18 worst rails. Counting the accepted rails, a total of 30, 19 are best rails, 5 are second-best, and 6 worst. As already shown, of these 30 rails, which might be accepted on the ground of their bending weight being below 3000 pounds, only three of them could pass the gauntlet of all the other five specifications, and one of these three is a second-best rail.

I think I have now proved my first proposition, but I must anticipate an objection which Dr. Dudley may possibly raise. He may say that my argument against his formula, based upon the rejection of 61 rails out of 64, is invalid, because these rails were not made according to his formula. Let them be made according to my formula, he may say, and they will not be rejected, and they will give good service. I regret that he has given us the record of only three rails which do conform to his formula; they are not sufficient in number to draw valid conclusions from, but, such as they are, here is the conclusion they lead to. Two of them are slower-wearing, one a faster-wearing rail; therefore, out of three rails which conform to the formula, the chances are that one rail will not be a good one. Are the railroad companies satisfied with such a result as this? But suppose, for the purpose of admitting a greater number of rails into our accepted list, we relax the specifications slightly. We will say that rails must be made according to Dr. Dudley's formula, but if a rail happens to conform to five of the six specifications and fails in only one, and that one manganese, the least injurious element considered (Dr. Dudley himself considering it only one-fifth as bad as phosphorus), then we will not reject that rail. Our list of accepted rails will then read as follows:

No.	Service.	Order in Dr. D.'s table.	Max. load.	Deflection.	C.	P.	Si.	Mn.	P. units.
920	Level tangent	10th in 16	2630	190°	·293	.063	.039	326	24.6
932	" curve, low side,	1st " 8	2340	190°	.269	.047	.026	.372	22.4
943	" " "	6th " 8	2780	159½°	.314	.061	.025	.602	29.8
931	" " high side,	5th " 8	2430	190°	.260	.047	.029	.416	23.1
887	Tangent grade,	1st " 16	2770	190°	.287	.048	.023	.435	24.2
886	" "	13th " 16	2790	190°	.349	.069	.026	.404	27.9
899	Curve gr., low side,	1st " 8	2620	190°	.263	.051	.038	.326	22 3
910	" " "	5th " 8	2660	190°	·343	.098	.020	.478	31.8

Here are eight rails, unquestionably the softest rails of the series,

conforming exactly to Dr. Dudley's specifications, except four which have manganese less than one-tenth of a per cent. higher, and one with manganese two-tenths of a per cent. higher than the specifications. We ought to expect that all or nearly all of these eight rails would be included in the thirty-two rails designated by Dr. Dudley as slower wearing, but, on the contrary, there are only three of them so included, and five of them are the faster-wearing rails. It has been said that exceptions prove the rule, but there is such a thing as having more exceptions than rule, and I think we have such a case before us.

After Dr. Dudley has spent some years investigating the difficult problem of determining what physical or chemical properties have an influence upon wear, he tabulates his results; he studies them carefully; he then proceeds to write his report and to draw his conclusions. In the report we find the following words:

"Giving our attention now to the tables, I think the first observation will be that there is no absolute gradation in physical qualities, or in chemical composition, applying to every rail in each group, which corresponds to the gradation in amount of metal lost per million tons."

Then he tells us we ought not to expect such uniformity, for two reasons:

1st. Errors in determining loss of metal and tonnage.

2d. I quote his own words: "I am not aware that it is known as yet exactly what wear is, or what it is dependent upon; . . . whether wear is a direct function of the tensile strength of steel, or of its elongation, or of its elastic limit, or of its resilience, or any combination of these, or indeed, as seems somewhat probable, of the amount of distortion by bending that a piece of steel will suffer, is a problem yet to be solved."

It certainly is a problem *yet to be solved*, and it will take many years to solve it. Dr. Dudley should have stopped here, and drawn the conclusion which I have drawn, namely, that, within the wide range of analyses and bending tests which I mentioned in the first part of these remarks, as far as these sixty-four tests show anything, they indicate that whatever wear is or may be dependent upon it is not dependent upon carbon, phosphorus, silicon, manganese, bending weight, and deflection. Instead of this, in one breath he admits he does not know what wear is dependent upon, and in the next he formulates the extraordinary *non sequitur* that it is dependent upon carbon, phosphorus, silicon, manganese, bending

weight, and deflection, and recommends that the Pennsylvania Railroad Company demand that rails be made on specifications, based on these six variables, so narrow, that to fill them would cause the constant rejection of enormous quantities of steel, and a consequent enhancement of the price of rails, probably ten or twenty per cent., without any certainty that such rails would be any better than those the steel-mills are now making.

I earnestly hope that the investigation which Dr. Dudley has so ably carried on will be continued. I hope the Pennsylvania Railroad Company, or preferably a combination of several railroads, will institute the prolonged investigation which I think will be necessary to solve this deep problem; that they will take a hundred or more rails, watching and noting down carefully every detail of their manufacture as well as their analysis; that they will be carefully weighed before, during, and after service; that their crop-ends will be tested before service, and the rails themselves after removal; that all the sources of error which Dr. Dudley admits in the present investigation may be removed, and that enough facts may be gathered and tabulated so that the conclusions which may be drawn from them may be apparent to every one without labored discussion or heated argument. But I venture to prophesy that after this investigation shall have been completed, and a formula adopted which shall be satisfactory to both manufacturers and consumers, that formula will not be the one now under discussion.

I hope Dr. Dudley will pardon me if I have been unduly severe in my criticism, and consider that I have written my remarks hastily and at a time which should have been given to needed rest. I differ with him only as regards the conclusions which he has drawn. I appreciate the value of his labors, and only make public my own conclusions in the hope of contributing to the advancement of the science of steelmaking, in which we are all so deeply interested.

Dr. August Wendel, Troy, N. Y.: Dr. Dudley's last paper gives, certainly, very valuable and interesting information regarding the wear of rails under different conditions. His results concerning the composition of rails, explode, rather startlingly, some old theories regarding the wear of rails, and I think after his formula is simplified it will be *one* good formula to work by.

As he now arrives at the same conclusions reached in his first paper, some of my remarks will apply to both, although I would

not attempt to add anything directly to the distinguished criticism the first paper received.

Regarding his silicon percentages, I must say I cannot see any reason why they have not been disregarded entirely within the limits of his investigation. In following Dr. Dudley's reasoning in the use of averages and applying inductive methods, I cannot see what importance can be attached to this element, since, in his first investigations, the good and bad rails averaged nearly alike, and in his last series the rails which wore best showed even more silicon than the bad ones. I regard, therefore, the silicon an inconsiderable factor in making out the phosphorus units, without considering here the actual influence of this element on hardness,—an influence which is greatly overestimated in the formula.

With regard to the effect of manganese, I cannot agree with his conclusions. In ordinary working with full-blown steel, manganese is more or less the function of carbon, provided the spiegel is constant, and consequently should not be introduced into a formula for daily working as an independent coefficient.

In March, 1875, I made a report to my employers concerning the unsatisfactory working of steel in blooming.* I then came to the conclusion that steel ingots in order to roll well ought to contain:

$$Mn = 0.8\ (C + \tfrac{1}{2}\,Si) + 4\ P,$$

these symbols standing for the respective percentages of the elements. I maintain to-day, that for good results in blooming, this percentage of manganese ought to be aimed at for rail steel. For this reason I would sooner undertake to make steel according to Dr. Dudley's original formula, viz.:

Carbon,	0.334
Silicon,	0.060
Phosphorus,	0.077
Manganese,	0.491

than according to the one in which he tries to make concessions to the manufacturers, viz.:

Carbon,	0.30
Silicon,	0 04
Phosphorus,	0 10
Manganese,	0 35

* Transactions, vol. iv., page 364.

Now in spite of all the progress in steel manufacture, we have not succeeded in making up steel by prescription, and what would therefore become of the ingots in which manganese for some cause or other should happen to fall below Dr. Dudley's meagre allowance? The answer will be: "Works must return to the old practice of hammering ingots," but I doubt very much whether even by hammering, a sounder bloom, and as a consequence, a better rail is obtained.

German government officials, who as a rule are not happy unless they can make things unpleasant for somebody, must have got hold of Dr. Dudley's formula, as they lately insist upon steel being hammered. Now, there is not the least doubt that some of the steel under Dr. Dudley's investigation was hammered, but I do not deem it necessary to resume that practice, if a larger manganese percentage is used.

I am greatly encouraged in this statement by the analysis of the *rara avis* of the series. I refer to the one showing 0.48 silicon. I would consider it sound metal, since it satisfies my equation regarding manganese, and still, in spite of its increased hardness and its enormous phosphorus units, is satisfactory in wearing capacity.

The conclusions of Dr. Dudley's ingenious experiments seem more simple than he cares to admit, and could be condensed by simply saying: "Use iron low in phosphorus, and do not make the steel too hard."

Regarding tests of steel made from such iron, I would even be more stringent than Mr. Sandberg. Of each blow I would make a bar about one inch square, and bend it cold. It should not be so hard as to resist bending to the shape of a horseshoe, nor should it be so soft as to bend 180 degrees without showing signs of fracture. There would thus be obtained a quality of steel that would more than satisfy Dr. Dudley's pretty theory of infinitesimal teeth by creating those whose tendency would be to neither flatten nor to bend. I think that in making this test, and supplementing it by the carbon test, manganese and silicon would regulate themselves much more nicely than any specification could effect. Every steel-maker knows that, should the silicon run high, the heat is blown too short, carbon will be increased considerably, and the test will not stand. On the other hand, if manganese is high, the heat has received too much spiegel (and that is simple awkwardness), and carbon would show the same result as above.

In conclusion, I should think that railroad authorities, under all

circumstances, would prefer the steel with which they are now familiar, to a specimen that Mr. Sandberg has described as having broken into seventeen pieces under the wheels. After blowing such low manganese steel, it may be coaxed into a rail, but it is a wonder that it holds together so long as it does, with so great a number of minute flaws.

I would not in any way depreciate chemistry, but I think it should be kept in its proper sphere. Let the chemist look after the quality of pig metal, and apply common sense in the avoiding of extremes, then the most fastidious railroad cannot find fault with the result.

PROFESSOR EGLESTON, NEW YORK CITY: It is not my place as an engineer to apologize for the chemists, but as no one seems disposed to do so, and as they have had more than their share of criticism, I am glad to say that I believe there are chemists in this Institute whose work and word are just as reliable, and perhaps even more so, than that of the average engineer. But we ought to make a distinction; there are chemists and chemists. With the ordinary commercial chemist, who looks upon the science as so much merchandise, I have not a particle of sympathy; but with the chemist who looks upon his profession as engineers do upon theirs, I have every sympathy. When manufacturers and engineers go to a chemist and ask him to make an investigation, and screw him down to the lowest point, turning the equivalent of his brains into cents and mills, they usually get an exact equivalent in poor work for miserable pay, and no one has or should have any sympathy with them, and the manufacturer under these conditions has no right to ask for any, and no reason to criticise any work that he may get under such circumstances. But I am disposed to think that the chemists who have been represented and discussed at this meeting do their work conscientiously, and that it is as reliable as that of almost any profession.

I believe, however, that this problem of steel rails is being investigated in a wrong direction. I said so at the Pittsburgh meeting, and I think the discussion of this meeting will prove it to all those who have heard it. I think the chemist is incapable of solving this problem unless he goes very far into the domain of physical chemistry, so far that it becomes physics and not chemistry; and that the physicist will be the one on whom we must rely in the future for the elucidation of the subject. The chemist may aid the physicist, but it is my decided opinion that we are looking in the wrong place to get the explanation of the phenomena.

Attention was called at the St. Louis, and afterwards at the Baltimore meeting, to the fact that the pounding which a rail receives from the falling of the engine from a high rail to a low one was sufficient in many cases to account for effects which have not been explained in this discussion. This statement was made after an extended observation had been made of rails laid over many hundred miles of railway in Europe. But if it is true, as Mr. Cloud stated in his papers read yesterday, that the blow of the engine is repeated not only at the end of the rail, but every time the driving-wheel makes a revolution, it will explain much of the giving-way of the rails over their whole length, and the effects of these blows on the physical condition of the steel should be very carefully investigated. It was shown in the discussion of the law of fatigue and refreshment of metals at the meeting in Montreal, that every blow was accompanied by a physical effect which could be rendered distinctly visible. The blow and pressure of the gag which always leaves its trace on the rail is certainly less of a physical effect than the constant and rapidly repeated series of blows which the rail receives from the continual passing of trains, yet the gagging always injures a rail and sometimes destroys it.

At the Baltimore meeting two rails were shown which had been placed in essentially different conditions, and which had been subject to a cold flow of the metal in every part of the rail even to the very outside of the foot. Mr. Metcalf yesterday showed this same kind of a flow in rolls. He also spoke of the ignoring of the copper in the analyses of steel rails. At the Washington meeting in 1876, the statement was challenged that good steel rails had been made containing any very large percentage of copper, and though repeatedly promised the analyses of such rails they have never been produced. Some years ago, in visiting one of the largest steel works where the ingots are compressed, I noticed a jet of blue flame passing out from the bottom of the ingot mould, which I at first thought was phosphorus, but which I afterwards determined to be copper. Certainly, if there is enough copper in the rail to allow of its becoming visible in the color of the flame, there must be enough to influence its physical condition and its life, and we cannot afford to neglect it.

I have also had occasion to show that bubbles produced in the steel ingots were never rolled out of them, and that if they were once in the ingot they remain in the rail and arrange themselves in such positions that they were sure sooner or later to engender

a weakness in the direction which the cavities take. As these bubbles are never rolled out as the rail wears, they come to the surface, and the rail which shows a chemical analysis which is perfect, becomes imperfect from a physical defect. Every one who is familiar with the breaking of metals in a testing machine has been made aware of the fact that these bubbles will often cause metals whose analysis is faultless, to break with a very low tensile strength, while a piece without bubbles, taken from the same sample, will break with a high one. These bubbles are sometimes finer than pin-holes. I have, in investigating this fact in railroad material, occasionally come across iron and steel which were so fatigued at the time that they left the rolls, that they were really unfit for service; and I have seen new rails which I should not feel justified in placing in any other position than on a side track. This question of fatigue in the course of manufacture has not been discussed at all so far as I know. I took occasion to show in the St. Louis meeting, that a rail taken from the Northern Railway of France, which I had the pleasure of examining, and which was condemned as good for nothing, and which the manufacturers were obliged to replace, when brought to Paris and submitted to chemical and physical tests, proved to be as good as any rails which were in the service. These kind of physical defects are the ones which are to be looked after; and, in fact, nearly all the defects for which a chemical solution is demanded are physical. I have within the last year had occasion to examine metals and alloys which are fatigued, and find that while chemically the same, they act physically so entirely differently that I hope at some future meeting of the Institute to bring the matter before you.

I am at a loss to know why certain chemical substances which we know are in the iron, or are likely to be there, should not be determined, and their effects discussed. Copper is one of these, sulphur is another, titanium and vanadium are known to be sometimes there. Why should not the effects of these substances be discussed?

Mr. Metcalf has alluded to the question of occluded gases. I have had occasion to show recently in my laboratory that as a general thing metals and alloys which were brittle from fatigue, contained a much larger amount of gas than the same metal which was not fatigued. I have also ascertained that the metals in this condition go into solution in a manner quite different from those not fatigued. I think also that the place from which the sample is taken from the rail will make some difference with regard to the results. Some one, I do not remember who, made an investigation some

years ago upon the effect of having the rails always rolled in the same direction, and also of having them rolled backwards and forwards, and showed that under the latter course there were of necessity weak spots somewhere near the centre of the rail, yet in all this discussion the methods of rolling have been passed by almost in silence.

Mr. Sandberg in his paper mentions the idea of using a registering dynamometer attached to the punching machines, and of determining the quality of the metal by the resistance which is shown. I think the first idea of this kind was published by Professor Langley, then of Pittsburgh, who, while making some investigations for Messrs. Miller, Metcalf and Parkin, announced as the result of a series of dynamometric experiments that abrasive resistance was the term which should be used in regard to steels of different wearing qualities. I have had extremely delicate dynamometers attached to the instruments of precision with which I am making the investigation on the fatigue of metals, and hope soon to communicate the results of the investigation made with them to the Institute.

I wish again to call attention to the fact that we are using the words "hardener" and "hardness" without any real idea of the meaning of these words. When we say hard and soft, as we have been constantly doing during this discussion, is it quite sure that every one has exactly the same meaning in his mind? Certainly, when hard is used in distinction from soft, we mean not the capacity of wear, but the capacity of resistance to penetration, to fracture, or some other resistance, and do not always mean the capacity of resistance to abrasion or crushing, which the discussion would sometimes seem to imply were the only qualities requisite to constitute a good rail.

J. W. CLOUD, ALTOONA, PA.: I would call the attention of the Institute to the title of Dr. Dudley's interesting and valuable paper, —"The Wearing Capacity of Steel Rails in relation to their Chemical Composition and Physical Properties." Here are two separate and distinct questions: 1st, The wearing capacity of steel rails in relation to their chemical content; and 2d, the wearing capacity of steel rails in relation to their physical properties.

The discussion has been almost exclusively confined to the former question, on which there may be many differences of opinion in matters of detail without greatly affecting the result. The latter

question has been ignored, and I wish to call attention to it, particularly, because it is the practical question after all from the consumer's standpoint, and because the paper under discussion is more decisive on this question than on the other. In fact, I think we must admit that Dr. Dudley has established his main point, viz., that the softer steel, physically, gives the slower wear, contrary to general belief among engineers in this country.

Of course, we are all interested in the whole subject from a scientific standpoint, but as the discussion has been participated in largely by manufacturers of steel, with a business animus, and as they have endeavored to overthrow Dr. Dudley's chemical recommendations because they are necessarily the most vulnerable points in the paper, I wish to recall attention to the facts of the physical properties as being the consumer's only practical guide, and as affording the most conclusive results in the data before us.

The consumer of steel rails cannot test every blow chemically, but he can do so physically, and it is my opinion that a bending test of a whole rail section, say three feet long, under steady pressure, instead of a drop, with a specified deflection, without cracking, and a load not to be exceeded to produce this deflection for each rail section, will be a good practical test, not burdensome to manufacturers, and one that will insure consumers such a degree of softness in steel as they may desire.

They should not attempt to dictate to manufacturers how this degree of softness shall be obtained chemically, but allow them full freedom to do as they please, so the proper physical properties are had. Further, we are now in possession of the information requisite to make such specifications with the certainty of greater safety as well as more economical results in the life of rails.

I have recently had opportunities at Altoona, to see other and very convincing evidences of wear, as compared with physical softness. The locomotive driving-wheels probably cause at least one-half of the wear of rails, and the forces which go to wear the rails from the tires, must react with similar intensities on the tires themselves. We therefore have in driving-wheel tires, an opportunity to see the wear in a more concentrated form, so to speak, or with rates as well as differences magnified. I have recently found differences of one inch to two inches in circumference of two tires on the same axle when coming to shop for turning, and it is invariably evident that the smaller tire is much the harder, the chips from it being short and brittle, while chips from the larger tire are much

longer and tougher. In the worst case I have observed, viz., two inches difference in circumference, this difference in hardness, as observed from the cutting, was more marked than in the other cases. Tires are always grouped in sets by the manufacturers from their knowledge of the chemical composition of the steel, with an attempt to get those in one set which have the same degree of hardness, so that the wear shall be equal all around; they succeed pretty well on the average, but I have been noting the exceptions.

JACOB REESE, PITTSBURGH, PA.: I have been very much interested in the reading and discussion of Dr. Dudley's paper. As far as it relates to the data of work performed by the rails, and the determination of their physical and chemical properties, I have nothing but commendation of Dr. Dudley to express, as the investigation covered a greater range, and was performed with more care in detail, than any similar work which has come under my notice. But I beg leave to differ with Dr. Dudley in his conclusions.

What are the factors of hardness? Are they not carbon, silicon, phosphorus, and manganese? Now it is an undisputed fact among metallurgical experts that pure carbon and pure iron make the best steel of all degrees of carburization, and for all purposes. While carbon hardens, it also strengthens the metal, but silicon, phosphorus, and manganese, in hardening, make the metal also brittle, and are injurious in any amount. Carbon should be called a *strengthener;* and I claim that a steel rail made hard with carbon, with the other three hardeners absent or reduced to a minimum, will carry a greater tonnage than any of Dr. Dudley's soft rails.

But until the basic process is put into operation in this country we cannot expect to produce Bessemer or open-hearth steel without the presence of silicon, phosphorus, and manganese, in considerable quantities, and I greatly doubt the possibility of reducing the percentage of any of them by the present practice without seriously diminishing the output, and correspondingly increasing the net cost of production; which is an important question, since the increased life of the rail may be more than balanced by its increased cost.

I think that the soft rails performed a greater amount of work, because they contained a less amount of silicon, phosphorus, and manganese (*brittlers*, if I may so term them), and that carbon does not reduce the wearing capacity of rails. I believe that a rail made by the basic process, with silicon, phosphorus, and manganese reduced to a minimum, and containing 0.60 carbon, will be stronger

and tougher, and will carry double the tonnage of any of Dr. Dudley's soft rails.

C. E. STAFFORD, STEELTON, PA.: I must confess my high appreciation of Dr. Dudley's conscientious and painstaking work, and of his scientific methods in obtaining the data; but with his method of handling these results and with his conclusions drawn therefrom I cannot agree. The reasons for this difference of opinion I will endeavor to explain.

It is apparent on inspecting his Plates 6 and 7 that the majority of the slower-wearing rails are from the north track, and generally have a longer time of service, a greater average tonnage per rail, and a smaller average tonnage per year per rail than the faster-wearing, the majority of which are from the south track, and generally have a shorter time of service, a smaller average tonnage per rail, and a greater average tonnage per year per rail. Have these facts any significance? Have these differences of conditions to which they are subjected any bearing on the relative wearing capacity of these rails? I venture to say they have. I think, after a study of Table I (page 575), (an arrangement of lines 17 and 18 of Plate 8), in connection with Plates 6 and 7, we will find that the slower wear of the 32 best rails is only partly due to qualities inherent in the rails themselves, but is principally due to external conditions favorable to slower wear.

In regard to the north and south track, we know that over the south track come the loaded cars from the West, and that over the north track these cars return, most of them, empty. It is evident that this means for the north track a less average tonnage per rail per year; or, in other words, a lower wheel tonnage. When the load per wheel is less, the resistance and consequently the wear must, necessarily, be less, other things being equal.

Time of service, also, has an important bearing on the question in hand. It has been only within the last five or six years, as Dr. Dudley has pointed out, that the roadbed of the Pennsylvania Railroad has reached its present admirable condition. Before this time the roadbed was more elastic, more yielding (and probably not uniformly so) than at present. These circumstances might cause a softer rail to be more durable than a harder one, owing to the fact that it would yield more or less to the bending force of the passing load and would thus get a bearing on each cross-tie. The harder rail, on the other hand, being stiffer and more unyielding, would not

have this bearing uniformly, and would thus, to a greater or less degree, be subjected to the same conditions as a beam under shock, vibration, and a rapidly moving load. Under such conditions, I believe, a harder rail would crush, break, and perhaps wear out more easily and quickly than a softer rail. This agrees with Dr. Dudley's statement: "With the improvement in maintenance of way, during the last five or six years, the removal of rails from track from the first two of these causes has quite notably diminished." Under conditions as they now exist on the Pennsylvania Railroad, I believe, the harder rail will give the slower wear. With the ballast comparatively solid and unyielding, as at present, the rail, having a more nearly perfect and uniform bearing, and acting less the part of a beam than that of an anvil must, in my opinion, be a hard one, to withstand the pounding of the locomotive and the abrasion due to combined rolling and sliding friction.

Viewed in this light a hard or soft rail would be respectively preferable as the maintenance of way has become more or less practically perfect. Of the seven rails, in track seven years or less, included in the slower-wearing division, and whose phosphorus units average 40.95, there will be found but one showing, under the same conditions, a slower wear for the softer rail. As these rails were put in track during and after the improvement in maintenance of way, they tend to confirm the proposition that with a well-ballasted track the harder rails give the slower wear. Next under the head of time of service comes the consideration of the wheel tonnage (the average tonnage per rail per year in Table I). This, as pointed out by Mr. Ashbel Welch, has been increased over 60 per cent. within the last five or six years. The speed and the weights of locomotives, cars, and trains have also been increased within this period. With the increase of each of these quantities resistance increases. This increased resistance must be overcome by increased friction between drivers and track, which, other conditions being the same, must result in greater or more rapid wear than formerly. Further, with greater speed and weights the defects in the rolling stock—as flat and improperly coned wheels, worn tires, etc.—must cause greater injury to the rail. It must be borne in mind that the average wheel tonnage of the north track is less than that of the south track during the entire period considered.

It will be noticed, in Table I, that the average tonnage per rail (not the average tonnage per rail per year) of the slower-wearing rails is much greater than that of the faster-wearing. I call atten-

tion to this fact because I believe it to be important. We know that the head of a rail when new, is more or less rough, and that this roughness wears off rapidly with the first few million tons of service; consequently, if the loss is determined when the tonnage is low, the loss per million tons will not show the actual wearing rate during its future use. Of course, this influence on the wearing rate becomes less and less, as the tonnage increases. After wearing off this roughness, it may be that the succeeding few million tons cold-roll or hammer the surface, causing it to more successfully resist subsequent wear. From the history of the road it is evident that those rails having a long time of service possess advantages in favor of slow wear. Not only have they a high tonnage, but they also have had a preparation and wear of the surface while the wheel tonnage was light; the later rails have, on the other hand, been subjected from the start to a heavier wheel tonnage with the accompanying conditions unfavorable to slow wear. Upon the relative wear on different grades, and curves, and combinations of the two, it is unnecessary to dwell.

Having tried to make plain the tendency of each of these conditions, I will now tabulate them:

Conditions Favorable to Slower Wear.	Conditions Unfavorable to Slower Wear.
North track.	South track.
Lighter wheel tonnage.	Heavier wheel tonnage.
Longer time of service.	Shorter time of service.
Greater tonnage.	Smaller tonnage.
Lighter grade.	Heavier grade.
Lower degree curve.	Higher degree curve.

I do not say these conditions will absolutely determine the relative positions of the 64 rails, because we do not know the ratio of the wear of a given rail under a known set of conditions (favorable, or unfavorable, or both), to the wear of the same rail under another known set of conditions; also because of conditions not given in the data, and because of exceptions named below. But what I have tried to make plain in the preceding remarks is that, in general, the 32 best rails have been in service under conditions, in the main, favorable to slower wear. When this is not the case, the rail, measured by phosphorus units, is hard, and with one exception (rail 915 referred to later), harder than its companion subjected, as far as known, to the same conditions.

To put it more concisely, the slower wear of the 32 best rails is

due to external conditions, which, when summed up, are favorable to slower wear, and not to qualities inherent in the rails themselves; except in a few cases, and these when the rails are hard. If this statement is true, then Dr. Dudley's conclusion, that the slower wear of the 32 best rails is due to their being softer than the 32 faster wearing does not hold.

With the object of learning further what averages of these 64 rails may point out to us, I have arranged them differently, as seen in Table II. We may thus be able to learn whether the indications of the first averages are confirmed or not; or whether the first averages, when studied with the second, may fairly be interpreted to point to, or at least not disprove, conclusions radically differing from those first drawn.

TABLE I.

	North track.	South track.	Total.	Average time of service.	Av. wear per million tons.	Average tonnage per rail.	Average ton per rail, per year.	C.	P.	Si.	Mn.	Phos. units.
All conditions, slower-wearing.	22	10	32	9 y.—5½m.	.0506	53,737,156	5,686,104	.334	.077	.060	.491	31.3
All conditions, faster-wearing.	10	22	32	6 0	.1028	40,406,260	6,780,871	.390	.106	047	.647	38.9

TABLE II.

N. track rails.....	32	0	32	9	5¾	.0638	46,545,146	4,906,225	.329	.071	.064	.506	31.4
S. track rails.....	0	32	32	5	11¾	.0740	47,285,770	7,978,227	.395	.111	.043	.631	38.9

In Table I, which we have just been considering, Dr. Dudley has found that 32 rails of a certain average chemical composition, show a much slower wear than 32 rails of a different average chemical composition. The 32 slower-wearing rails averaging softer than the 32 faster-wearing, the conclusion is drawn that this slower wear is due to this fact. Apparently, this inference is true, but as we have just seen, this slower wear is probably due to other causes. In Table II we have a comparison of rails in the north and south track. This gives us hard and soft rails averaging practically the same chemically as those in Table I, but showing a decided difference in the wear per million tons, comparing the soft and hard of the one with the soft and hard of the other, respectively; also, in the ratio of wear between the soft and hard of each. In Table I this ratio is 1 to 2.03; in Table II, 1 to 1.16. Even this slight difference probably would not have appeared if the north and south rails had

been equal in number in both curves and tangents. By consulting Dr. Dudley's Plates 6 and 7 the distribution will be found to be as follows: In tangents, 19 north track rails and 13 south; in curves, only 13 north track rails and 19 south. As it is, in the south track rails with a wheel tonnage (average tonnage per rail per year) 62½ per cent. greater, there is a wear only 1.6 per cent. greater; and this with nearly equal average rail tonnage on both. With these circumstances in mind we may fairly conclude from Table II that, under the same conditions, the harder rails would give the better wear, which indication Table I does not contradict. This conclusion, like the one before, is in favor of the harder rails.

We have considered the conditions furnished by Dr. Dudley favorable and unfavorable to slower wear. That there are other conditions which materially affect the relative wear of rails will readily occur to all.

Among others, in addition to those given, are the following: Whether the speed is the same over all of the rails; whether the rail is subjected to more than ordinary wear by the stopping and starting of, or by the decreasing or the increasing of the speed of trains, as at or near train and watering stations, switches, crossings, sidings, bridges, tunnels, grades, curves, etc.; whether on tangents both sides of track at the same place are at the same level; whether on curve, the rail is taken near entering tangent or elsewhere; whether the elevation of the outer rail in each case corresponds to the average speed of trains at that curve; whether the character and condition of ballast and roadbed is the same for all rails; and other conditions known to those familiar with maintenance of way.

These conditions, more or less local in their character have, it seems to me, been too little considered in the study of "the wearing capacity of steel rails with relation to their chemical composition and physical properties."

With these circumstances in mind we must agree with Mr. Hunt that "averages are dangerous." In comparing different sets of rails, when, in each set, varying quantities (conditions) too indefinite to be averaged or not averageable are associated with others which are definite and can be averaged, and when the maximum and minimum in one set are greater and less respectively than the maximum and minimum of the other, and where a quantity in one rail differs greatly from the other rails in the same set, making the average to differ widely from any quantity of the same kind in that set, can

averages give conclusions which can reasonably be accepted as true beyond a doubt? I do not think they can. We have seen that widely different conclusions *can* be drawn from indications given by averages made up from different arrangements of the same rails. Indeed, I believe, that conclusions drawn from averages made up from any number of rails under so many and such different conditions would be of value only when confirmed by other data.

To properly study the relative wearing capacity of steel rails with reference to their chemical composition and physical properties, we must compare rails subject to the same conditions, as far as is practical, and which only vary in their chemical composition and physical properties. I have attempted to do this in the following table, made up from Dr. Dudley's level and grade tangents and grade curves. The members of each group have been in the same track the same time, are from the same locality, and have the same grade and curvature (if any); or, in other words, have been subjected to the same conditions, as far as known. It will be noticed that Nos. 893, 920, and 928 of the level and grade tangents have been omitted, and also

No. of group.	No. of rail.	Time of service. Y.	Time of service. M.	Track.	Grade.	Curve.	Tonnage.	Phos. units.	Loss per yard.	Loss per million tons.	Ratio of Loss. Harder rail = 1.
1	881	11	1	North.	92.4		55,546,811	59.2	3.85	.0693	1 : 1.50
	882	11	1	"				28.1	5.78	.1040	
2	883	10	2	"	95.04		52,174,969	35.7	2.54	.0487	1 : .83
	884	10	2	"				32.7	2.13	.0408	
3	885	11		"	89.76		55,197,994	33.9	2.74	.0496	1 : 1.63½
	886	11		"				27.9	4.48	.0811	
4	887	11		"	89.76		55,197,994	24.2	2.13	.0386	1 : 1.61
	888	11		"				21.3	3.44	.0623	
5	889	5	11	South.	21.13		44,620,100	33.1	3.54	.0793	1 : .97
	890	5	11	"				41.7	3.61	.0816	
6	891	7	1	"	40.13		53,687,192	37.7	3.14	.0585	1 : 1.10
	892	7	1	"				33.7	3.46	.0644	
7	894	5	2	"	52.8		38,088,574	45.9	2.93	.0769	1 : 1.03½
	895	5	2	"				45.5	3.03	.0796	1 : 1.04½
	896	5	2	"				40.5	3.04	.0798	
8	913	9	4	North.			45,855,101	33.4	1.01	.0220	1 : 1.31
	914	9	4	"				26.9	1.32	.0288	
9	915	6	1	"			31,514,889	39.2	0.51	.0162	1 : 0.17½
	923	6	1	"				45.5	2.92	.0926	
10	916	6		"			31,127,829	37.5	1.42	.0456	1 : 7.12½
	917	6		"				45.1	0.20	.0064	
11	918	10	6	"			51,720,011	29.9	0.71	.0137	1 : 0.71½
	919	10	6	"				20.3	0.51	.0098	
12	921	5	4	"			27,622,230	37.9	3.05	.1104	1 : 1.50
	922	5	4	"				44.7	2.03	.0735	
13	924	4	1	South.			36,349,989	44.2	1.52	.0418	1 : 1.14
	925	4	1	"				43.8	1.73	.0476	
14	926	9	3	"			76,409,128	30.2	1.53	.0200	1 : 1.13
	927	9	3	"				28.1	1.73	.0226	
15	897	11	2	North (high side).	21.12	5°	52,370,617	33.2	7.31	.1396	1 : .96
	898	11	2					28.1	6.99	.1335	
16	899	11	2	North (low side).	21.12	5°	52,370,617	22.3	2.24	.0428	1 : .92
	900	11	2					32.2	2.44	.0466	

all of level and grade curves excepting Nos. 897, 898, 899, and 900, because of the impossibility of grouping them in the same manner, no two having the chemical composition and physical properties as the only variables. Phosphorus units have been taken to show the relative hardness. Of these 16 groups, 10 decidedly indicate slower wear for the harder rail.

Of the remaining 6 groups, three (groups 2, 9, and 15) come well within the limits of error (.25 pound per yard) inherent in the calculation of the data as pointed out by Dr. Dudley; they cannot, therefore, be considered as exceptions. Groups 2 and 15 are but little outside of the limits of error. Rail 923 of group 9 is obviously abnormal. This is probably due to its being overheated, which the chemical analysis shows might easily be the case, and which the physical tests and its low specific gravity tend to confirm. We may say, then, that 13 of these 16 groups fairly indicate, if they do not definitely point out, that, under the same conditions, the harder rail gives the slower wear.

Of course, these comparisons are too few to enable us to arrive at positive conclusions; but indications thus obtained are, I believe, far more valuable and trustworthy than those that averages would give us, made up from any number of rails under many different conditions.

Finally, it seems to me, that the conclusions arrived at earlier in my remarks, together with, and confirmed by the last, show strong evidence that, under the same conditions, the harder rail will give the slower wear.

O. CHANUTE, NEW YORK CITY: We are very much obliged, I am sure, to Mr. Sandberg for his paper upon "Rail Specifications and Rail Inspection in Europe." We have in the United States hitherto been inspecting rails somewhat haphazard, and we are glad to get the results of Mr. Sandberg's long experience.

We recognize that he was among the first, if not the very first, to apply more rational and scientific rules to the designing of iron rails, and, more recently, to adapt these rules to the designing of steel rails, to conform to the capabilities and requirements of this new material. Although we have generally adopted, in this country, sections for steel rails which many of our railway men think even better than those of Mr. Sandberg, he is nevertheless the leader in whose footsteps we have followed ever since it has been established

that the fish-joint was the best method of fastening the rails together at the ends.

We have not yet, however, been able to formulate or to adopt any well-established relation between the height and weight of the rail and the weight and speed of the engines, such as he indicates in his Table No. I. For instance, the New York Central rail is 4½ inches deep, and weighs 65 pounds per yard, while its locomotives are of 37 tons maximum weight. The Erie rail is $4\frac{5}{16}$ inches deep, with 63 pounds weight per yard, and the Pennsylvania rail is 4½ inches deep, with 67 pounds weight per yard, while the maximum weight of locomotives upon both these latter lines is 50 tons. Now which is right? I am inclined to believe that the Pennsylvania Railroad follows the better practice, not because the other rails are too light for the engines, but because inasmuch as steel rails wear out by abrasion, and not by lamination, the Pennsylvania rail promises to be serviceable until about 12 pounds of metal per yard are worn off from the head, while the Erie rail will probably have to be removed from the track when some 8½ pounds are worn off.

Timber is still so cheap with us that we have not hitherto concerned ourselves very greatly about the strength of our rails considered as beams. If after having adopted a rail section, say between 50 and 60 pounds, we have found it a little too limber under increasing weight of locomotives, we have simply put the ties nearer together, and we have thus arrived at the general practice of spacing them about 2 feet between centres, while I notice that Mr. Sandberg's calculations of required stiffness are based upon having the supports 3 feet apart.

We are careful, however, to limit the weight upon our driving-wheels to a maximum of 12,000 pounds (excepting a few experimental locomotives), and when our gradients and trains require more adhesion than can be obtained from the standard "American" engine, we think it better to adopt the "Mogul" type, with 6 drivers, or the "Consolidation," with 8 drivers; the latter having generally an average of but 11,000 pounds per driving-wheel, and being no harder on the rail than other classes of locomotives.

Believing that much of the wear of rails results from undue pressures, I have made some experiments to determine the area of the surfaces in contact between wheels and rails. These were obtained by jacking up a wheel, and introducing between it and the rail a piece of thin tissue-paper, underlaid with a slip of black manifold copying-paper. Upon lowering the wheel, it generally

crushes a hole in the paper, and gives a fair impression of the surfaces in contact. If the wheel and rail were inelastic, this contact would be a mere line, but as they both yield, it becomes a surface which varies with the weight on the wheel and with its condition.

I found that with 11,000 to 12,000 pounds' weight upon a locomotive driving-wheel of about 5 feet diameter the pressures were generally 35,000 to 40,000 pounds to the square inch, although they occasionally ran up much beyond this, but that with 14,000 pounds on a driver the pressures became from 50,000 to 80,000 pounds to the inch, or beyond the elastic limit even of steel.

I also found that under empty freight cars, with say 2400 pounds on a 33-inch wheel, the pressures were generally 20,000 to 30,000 pounds per square inch; that with the car loaded with 11 tons, increasing the weight to say 5150 pounds per wheel, these pressures became about 35,000 pounds to the inch, while if the car was loaded with 20 tons, thus giving 7400 pounds per wheel, the pressures increased to 50,000 or 60,000 pounds to the square inch.

As we increase the weight upon our cars, therefore,—and I believe this to be the correct and inevitable practice,—we must be prepared to find our steel rails wear out faster than they hitherto have done. We may, perhaps, reduce the pressure by increasing the diameter of car-wheels, but my own judgment is that we should endeavor to limit the weight on locomotive-drivers of 5 feet diameter to 12,000 pounds, and on 33-inch car-wheels to about 7000 pounds, so as not to bring crushing strains upon our rails and wheels.

I notice that Mr. Sandberg is disposed to think that our adoption of 30 feet as a normal rail length is an extreme limit. I believe, however, that our mills have found no difficulty in working up to this, and that we get only about 3 per cent. of shorter rails, under the provision that not more than 10 per cent. may be delivered under 30 feet, down to 25 feet. The difficulties which he mentions, as connected with ocean transportation of 30-foot rails, need not concern us much at the present time. I believe that the iron rail mills of this country have the capacity for turning out about 1,000,000 of tons a year, if so many tons of iron rails were called for, and that the steel mills have a present capacity of about 1,500,000 tons, and a prospective capacity, by the end of this year, of some 1,750,000 tons of steel rails per annum. Now this would furnish us enough rails, if fully employed, to lay or to relay 25,000 to 27,000 miles of track a year. We now have 93,000 miles of railway, of which about 60,000 miles are ten years old

and over. Allowing for the postponement of renewals in past years, double tracks, etc., I estimate that these railways will require some 800,000 to 900,000 tons of rails per annum for the next four or five years, to relay their tracks. We are also building some 7000 miles of new railway a year, a rate of progress, however, which I believe we cannot maintain without great risk of running into unprofitable investments, and bringing about a fresh collapse; but even if we do build 7000 miles a year, the aggregate demands for rails in the United States would not exceed 1,500,000 or 1,600,000 tons a year, or a little less than the estimated capacity of the steel works alone for 1882.

We are not likely, therefore, to import many rails from Europe, except occasionally on an emergency, and as a reminder to our manufacturers that there are other railmakers in the world; but if we do, let us not ask the foreign mills to grind off the ends of the rails, to make them exactly of even length, a foreign practice against which Mr. Sandberg so justly warns us. Neither shall we ask them to notch steel rails, except in rare instances, as most of our roads have now adopted, or are adopting, angle fish-plates, to which the notching is transferred, thus preventing creeping through the shearing resistance of the bolts; but we shall undoubtedly require them to drill all holes for the latter, and we find that a round hole, one inch in diameter, with a $\frac{7}{8}$ inch bolt, allows sufficient play to provide for contraction and expansion.

I made some experiments upon rail joints some years ago, which indicated rather better results than those given in Mr. Sandberg's Table No. I, Appendix, II. I found that the Erie standard steel rail, of 63 pounds weight per yard, upon solid bearings two feet apart in the clear, required the application of a weight of 60 tons on the head in the centre between the bearings to break it; that the old joint, composed of two flat plates, broke with 20 tons similarly applied; that the composite joint, consisting of one flat plate and one angle plate, broke with a weight of 25 tons, while the Erie standard joint, of two angle-plates 24 inches long, required 34 tons to break it. The flat-plate fishing was, therefore, 33 per cent., the composite joint 41 per cent., and the standard angle-joint 57 per cent., as strong as the solid rail, and the angle-plate fish showed such marked superiority, that our adoption of it was fully confirmed.

But we are especially obliged to Mr. Sandberg, for the details and blank forms which he gives us of his method of inspection. I wish particularly to call your attention to the blank for the inspection

book, Appendix IV, and to the form for reports, Appendix V. I think it would be well for us to adopt them for the use of our own inspectors in this country.

I do not, however, quite understand that clause in his specification for *steel* rails (page 30), which, under the head of "Tests," provides that: "2d, The rails must carry, in the same position, a load of — tons without breaking; after this the flange of the rail will be cut, and the rail broken. The fracture must show perfect welding, especially in the head." I thought it was a peculiarity of steel rails, that they were made from a single piece or ingot, and I am puzzled to imagine how the foreign makers contrive to get welds into them.

You will notice that nearly all my remarks refer to steel rails. I ought to have said so before, but the fact is, that when we now talk or think of rails, it is almost always of steel rails, for the days of iron rails are numbered. Already we see, when we examine one of these diagrams of prices of iron and steel rails, which look so much like the profile of a railway preliminary survey through a mountainous country, that the iron rails average only $5 or at most $10 a ton cheaper than steel rails; and the time cannot be far distant when steel rails will be produced as cheaply as iron. Indeed, I do not believe that any of our roads are now so poor as to be able to afford to buy iron rails, except, as I said before, upon an emergency.

The thanks and support of all railway men are therefore due to Dr. Dudley for his resolute attempt to ascertain the best composition and characteristics for steel rails. He may not as yet have gathered all the necessary data; his present conclusions may have to be corrected with reference to further facts; but I know that he is rendering valuable service, and I believe that he is on the right track.

I quite agree with the remark made by Mr. William Sellers, that the consumer should not undertake to prescribe to the manufacturer how he is to make his rails, nor what materials he is to employ, but should leave him free to select the surest and cheapest way of making a good article. The consumer is interested in the results only; but as the desired result in this case is that the rail shall wear as long as possible, and as steel rails wear out so slowly that we cannot know for many years which make of them is going to give the very best satisfaction; and while the economical results are so important, I believe that it is our duty to endeavor to ascertain the characteristics of the best rails, to assist the manufacturer to repeat his successes,

and to avoid his failures, by giving him whatever data we can gather as to the rails in our tracks.

This, as I understand, is what Dr. Dudley has undertaken to do, by ascertaining the chemical composition and physical characteristics of the rails which have best or worst worn on the Pennsylvania Railroad. While I will presently mention some considerations why his experiments may need to be revised, I yet recognize that he has done and is doing a great public service.

I must say, however, that the chemical composition which he recommends, does not strike me as a particularly soft steel. From the criticism which he has received here, I doubt whether Dr. Dudley himself now thinks that he has as soft a thing as he at first imagined. He advises that the phosphorus should not exceed 0.10 of one per cent., the silicon not above 0.04, and that the carbon should aim at 0.30, and the manganese at 0.35 of one per cent.

Now the Erie specification of 1876, adopted after consultation with Mr. Holley, reads: "Not less than $\frac{30}{100}$ths nor more than $\frac{45}{100}$ths of 1 per cent. of carbon; not more than $\frac{10}{100}$ths of 1 per cent. of phosphorus, and not more than $\frac{16}{100}$ths of 1 per cent. of phosphorus and silicon taken together. It may contain manganese, but shall be substantially free from other impurities."

In view of the fact that this was the state of the art about the time Dr. Dudley began his labors, and that really *soft* steel, that which we use for our boiler plates, only contains 0.08 to 0.15 of one per cent. of carbon, the term of "soft steel," which is much dwelt upon by the author, is rather a misnomer. What he is engaged upon is the ascertaining what are the exact chemical compositions which give absolutely the best rails, and how these shall be distinguished by physical tests. To accomplish this satisfactorily, he will have to gather a good many more data.

I think exception may be taken to the method by which Dr. Dudley has undertaken to ascertain the loss of weight sustained by each rail. Having taken up the whole rail, presumably about 30 feet long, he has cut out a slice from it, somewhere, $\frac{1}{2}$ an inch thick, and from this slice he has, by weighing and measuring, ascertained the loss of weight. Any one who will caliper a worn rail throughout its whole length, and thus ascertain how much greater is the wear in some spots than in others (differing $\frac{1}{16}$ of an inch in sections 2 inches apart in many cases), will have serious doubts whether Dr. Dudley has in each case hit upon the particular half inch which is a fair representation of that wear.

It seems also difficult to accept the inference to which this method of procedure leads him, when he says that "rails rolled at the same mill, at the same time, and with the same thickness of web, and same shape of foot, differed from each other in the original weight (*as computed*), from 1½ to 3 pounds per yard." Such is not our experience with Erie rails. We find that when the rolls are freshly turned up, the rails run about 62¾ pounds per yard, and that this weight is gradually increased as the rolls wear, to about 63¼ pounds per yard; each invoice of say 1000 tons (the shipments are generally of about this amount), averaging as near as may be the 63 pounds per yard represented by the standard template. Here, therefore, we have a variation of only ½ pound per yard, which is the limit assigned by our specification, and as I said before, it seems hard to believe that on the Pennsylvania Railroad, it could have been so much as 1½ to 3 pounds per yard.

I scarcely need to point out that if errors have thus crept into Dr. Dudley's estimates of the loss of weight sustained by each rail, his reasoning and conclusions will be affected throughout. I recognize the difficulty of getting at the wear of a rail the exact original weight of which is not known, but I believe Dr. Dudley will yet find better methods than that of computing it from a half-inch slice. Perhaps more satisfactory results may be reached by a careful calipering of the stem, head, and foot of the rail, and ascertaining its density, from which to deduce its original weight, deducting therefrom, to ascertain the wear, the actual weight of the worn rail. In fact, as he finally resorted to the method of averages, Dr. Dudley would have reached nearly the same result by assuming that the rails originally averaged of standard weight, and weighing together each group of eight rails, upon which he bases his deductions of wear.

I may also say a word as to the comparisons of wear upon the upper and lower sides of curves. These would have been more satisfactory if we had been told the differences, if any, which exist between the elevation of the outer rail on these various curves; also, the speeds at which trains generally run over them. The elevation of the outer rail being intended to overcome the centrifugal force, and this, of course, varying with the speed of the train, it is quite practicable for the track foreman to throw the wear upon the inner or the outer rail, by changing the elevation, or, in a less degree, for the locomotive engineer to do the same thing, by running faster or slower than the speed for which the curve is elevated. I hope, how-

ever, that Dr. Dudley will check over and continue his investigation. It is not improbable that the result will be still further to confirm his theory.

The railroad men of the whole country, who are specially interested in reaching sound conclusions on this subject, can materially assist in gathering additional data, by taking care to preserve rails which have worn exceptionally well or ill in their tracks, and sending them, with a statement of the particulars of each case, either to Dr. Dudley, if he will consent to test them, or to some of the Bessemer works from which they obtain their steel. All of these have competent chemists; they are vitally interested in maintaining a reputation for making good steel rails, and they would doubtless be glad to make arrangements to analyze and test any specimen rail which might be sent to them, in order to ascertain the causes of its excellence or deficiencies.

In listening to Dr. Holley's paper upon Rail Sections, I was reminded of De Quincey's ideal murderer, who, beginning with a murder which he thought little of at the time, had gradually fallen to robbing, drinking, and Sabbath-breaking, and so on, down to incivility and procrastination. For having adopted some years ago a rail pattern which I have never recommended to other roads, nor claimed credit for, I now unexpectedly find from Dr. Holley's paper that 62 per cent. of modern rail sections are fashioned after that pattern, that the considerations which guided me are thought worth enumerating, and that it furnishes a good text from which to preach a sermon to railroad men. I hope, however, to satisfy you that I am not entitled to as much notice as Dr. Holley has been pleased to give me.

As Mr. Welch has told you, we were both in 1874 members of a committee of the American Society of Civil Engineers to investigate the best form of rail sections. He then called my attention to the success of the thin flange and stem of his pattern of 1866, and I adopted them for the Erie Railway, which was then much in need of a standard steel-rail section. The bevelled head was furnished, ready made, by the sections of old rails which I examined, and was confirmed by the templates of worn wheels, twenty or thirty in number, which I obtained from locomotives and cars. I simply gathered the data, and was guided by them, as any one would have been in my place, and as in fact others had been, for I am informed that Mr. Sayre, of the Lehigh Valley Railroad, and Mr. Fritz, of the

Bethlehem Iron Works, had designed and rolled a similar rail, as early as 1870.

The Erie rail was originally designed to weigh sixty pounds per yard, this being the limit at that time imposed by the managers of the road. It took some months to get the pattern accepted, some of the rolling-mill managers declaring that it could not be rolled without producing a large percentage of imperfect rails. Mr. L. S. Bent, however, the superintendent of the Pennsylvania Steel Company's Works, thought differently and determined to try it. He found that the percentage of imperfect rails was actually less than with other patterns then in use, and he designed and introduced a number of steel rail sections on the same principle, which have become standards.

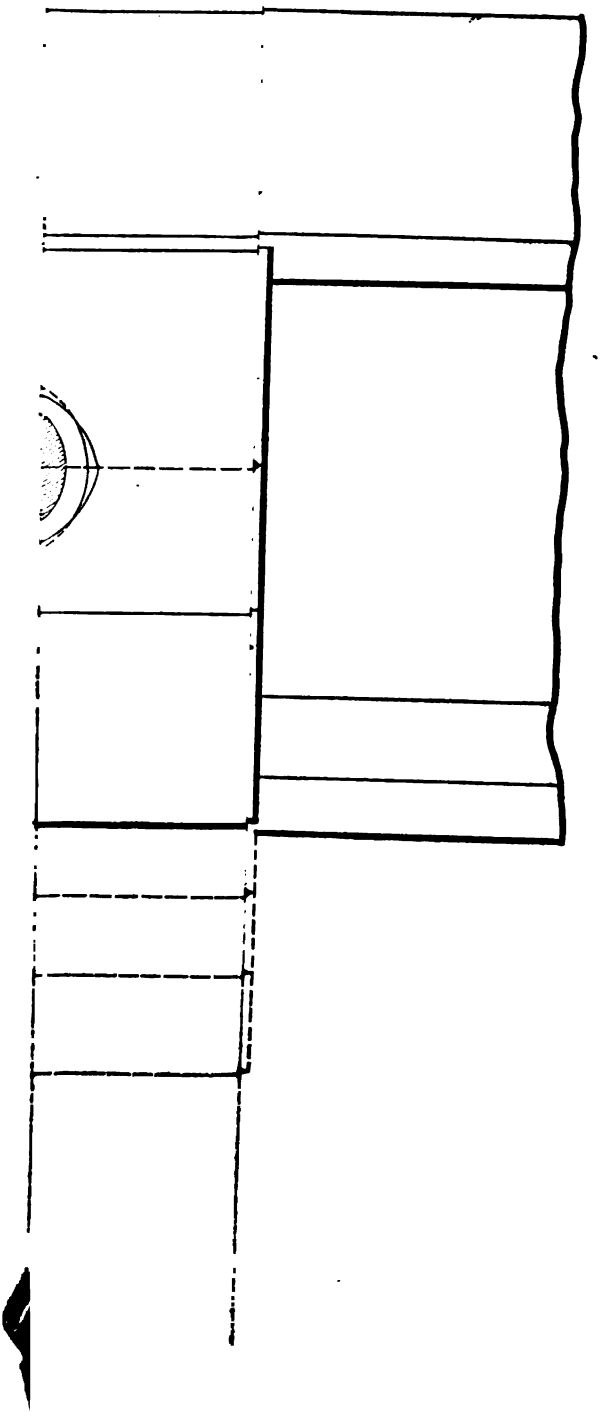
Some three or four thousand tons were rolled and laid of the original Erie sixty-pound pattern, and they have stood very well, but Dr. Holley having suggested that the thinness of the foot, in proportion to the head, might cause dangerous internal strains in cooling, and thus make the rail brittle and dangerous, a thickness of one-sixteenth of an inch was added to the foot, increasing the weight to sixty-three pounds per yard, and this has been the Erie standard section ever since. As I said before, in my opinion the Pennsylvania Railroad section of sixty-seven pounds per yard is better, as likely to wear about 50 per cent. longer.

Up to a certain point, there is an advantage in diversity of railroad practice. So long as the best device for a particular purpose is not ascertained, there is a necessity for experimenting, with the resulting variety of design. When, however, the best pattern is approximately agreed upon, the effort should be towards uniformity. This point seems now to have been reached about steel rail sections, although I had no idea this was the fact, and I hope the railroads will take advantage of the economy which Dr. Holley has shown us to result from the adoption of uniform standards.

He has called our attention to the importance of uniformity in fishing, and especially in spacing the bolt-holes, but he has not told us which he considers the best practice. I venture to present a drawing of the Erie standard joint. (See accompanying plate.) There is nothing novel about it, but the points which we think meritorious, are the following:

1st. The holes in the rails are placed as far from the end as we deem practicable. The centre of the first hole is pitched an even 4 inches from the end of the rail, and the second hole is 6 inches beyond this, or 10 inches from the end.

Chanute.



2d. These holes are drilled in all cases, are 1 inch in diameter, and as near the neutral axis of the rail as we can get.

3d. The fishing is done with angle plates, which we find about 70 per cent. stronger than flat plates. The notching, which is in the fish-plate and not in the rail, is spaced $3\frac{1}{2}$ inches from one end, and 5 inches from the other, so that when the plate, which is reversible, is applied to both sides of the rail, the notches are staggered sufficiently to avoid splitting the tie with the spikes.

4th. The allowance for expansion is made in the fish-plate, the two centre holes being spaced $8\frac{9}{32}$ inches apart. As the next holes are, of course, 6 inches beyond the centre holes, and the plate is designed to be 24 inches long, it will be noticed that if the man at the shears cuts it off of the right length, and the man at the punch centres it exactly, the distance from the centre of the end holes to the end of the plate will be precisely $1\frac{5}{8}\frac{5}{4}$ inches. I hope that Dr. Holley, who says he was appalled at the thought that the mind of man can hit perfection in spacing fish-plate holes within the 64th of an inch, will see from this brief exposition of the process, that it is more easy to accomplish than he supposed.

5th. The holes in the fish-plate are made oval to allow for expansion and contraction. The bolt, which is $\frac{7}{8}$ of an inch in diameter, is upset under the head to fill this oval hole, and thus prevent turning. It is provided with a hexagonal nut, under which we generally place a thin washer of wrought iron. We have very little trouble from nuts getting loose, so little indeed, that while we have experimented with a number of lock-nuts, we have not deemed it necessary to adopt any of them.

But I fear I am becoming wearisome by my discussion of these details, which would be more appropriate before a special committee on this subject, such as that appointed in 1874, by the Society of Civil Engineers. The main point before you, is that so well made by Dr. Holley, of the importance and economy of uniformity in rail sections and fastenings. Of that we have had some experience. We had on the Erie railway, when the new steel section was adopted, 12 patterns of steel rails, 29 patterns of iron rails, and 96 different styles of fastenings. These caused no end of annoyance, delays, and expense, in matching or mismatching them, taking up and changing about long strings of rails, and in the large stocks which it was necessary to keep for repairs. This has all been done away with, by the adoption of a single pattern of rail and of fastening, and the resulting economy fully confirms all that Dr. Holley has said. He

has shown us that the railroads of this country can save several millions a year by adopting uniform rail sections, and as unfortunately for him, he cannot patent his idea, it only remains for the railroads to adopt it, and to thank him for his paper.

DR. C. B. DUDLEY, ALTOONA, PA.: In rising to close this interesting discussion, I want, in the first place, to thank every one who has contributed to it for his full and open criticism. The work which has been done on steel rails, and which has been discussed here during these two days, was not done to establish any pet theories, nor to make out that any person was great or any person small, but with a sincere desire to get at what is the truth in regard to the wearing capacity of steel rails. There are enormous commercial considerations involved in this question, and, as I look at the matter, the more honest criticism and fair discussion there is, the more likely it is that the truth will appear.

And first I would like to say that it seems to me very little has been said here upon the main conclusion of the paper, namely, that the softer rails give the better wear. All sorts of side issues have been discussed; but this point, which is really the principal one at issue, has been largely ignored, and I cannot but feel that it still remains unshaken.

With regard to chemists and chemical work, there has been considerable said tending to throw discredit on chemists and their work; and while I believe that there have been in the past, are now, and may be in the future, a good many poor chemical analyses made, I also believe that chemists are, as a rule, as honest and competent as gentlemen who belong to other professions. There are chemists who are chemists, and chemists who are not chemists.

The determination of manganese has been called in question. Now I think the chemist at almost every steel works in the country will tell you that, in his experience, the manganese differs in different parts of the same ingot. Mr. T. T. Morrell, chemist of the Cambria Iron Company, whom I believe to be a thoroughly competent and honest chemist, tells me that he has often found different amounts of manganese in different parts of the same ingot. Come with me to Altoona, and I will take you into the machine shop where steel is being cut and shaped, and I will show you that it is often necessary to stop the lathe or planer and take a cold chisel to cut out a hard spot, or else run the risk of breaking the tool. This hard spot is simply a part of the spiegel which was not thoroughly mixed with the mass

when the steel was made. In the rapid methods by which steel is at present manufactured, time enough is not allowed for the spiegel to become uniformly mixed. What wonder, then, that chemists find different amounts of manganese in what is supposed to be, but is not, the same steel. Indeed I believe it is possible for the borings from one bore hole in the same ingot to be given to two chemists and to have them find different amounts of manganese, and yet both analyses be correct. And so, I say to the steel-makers: "Make uniform steel, and we, as chemists, will tell you what there is in it."

With regard to the determinations of manganese in the series of rails we are discussing, I would say, that I wish Mr. Wells was here, that you might see him for yourselves. When I began this work, I wrote to my old instructor in chemistry, Professor O. D. Allen, of the Sheffield Scientific School, to recommend me some one to help me. He replied that if Mr. Wells would come he could heartily recommend him. He had had two years' experience since his graduation, and, said Professor Allen, "I regard him as the best analytical chemist that has graduated under me." And I may add that both Professor Drown and myself graduated under Professor Allen.

Still further, it is simply impossible that any errors, either in the chemical analyses or the physical tests, should have had any influence in establishing the point that the softer steel gives the better wear. This follows from the way in which the work was done. First the physical tests were made, then the analyses, then the tonnage was computed, and finally the loss of metal was determined. So that we knew nothing about a rail until all the chemical analyses and physical tests were made. Furthermore, some of the rails that were selected as faster-wearing rails, when we came to get the rate of wear, were found to be slower-wearing rails. So that no previous bias of mind, or, as it seems to me, no possible errors in the work could influence the result.

Again with regard to sulphur and copper, it is said that these are of vital importance, and should have been determined. In answer to this I would say: Where is the man that can affirm, and back his statement by any analysis, that sulphur and copper have any influence on the wearing capacity of steel? I do not say that these elements do not have an influence on wear, but when this investigation was started the best information that I could get was that sulphur and copper are of vastly more importance to the steel manufacturers than they are to the consumer. And so I say that I believe the sulphur and copper are of importance to the makers of

steel, but of not so much importance to one studying its wearing capacity. If you want to know the sulphur and copper in these rails you may determine them.

Probably no one has thought over the question why some of the rails in this series seem to be exceptions to the general law more than I have. This suggestion in regard to sulphur and copper, and other undetermined substances, and especially, in my judgment, oxide of iron, furnishes a possible solution of the problem. If we knew every foreign substance which these rails contain, I doubt not but that some of the anomalies would be explained. And I would here like to ask chemists who have time to devote to such studies, to give us a method for determining oxide of iron in steel.

Another point made was the influence of heavier locomotives and cars on the wear of rails. If I understand this criticism it is this: Your slower-wearing rails had lighter wheel tonnage for at least a portion of their life—the earlier portion—while your faster-wearing rails have had almost altogether heavier wheel tonnage. In reply, I say the slower-wearing rails had during the latter part of their life the same heavier wheel tonnage that the faster-wearing had. All the rails were taken out of the track at the same time, and, consequently, so far as I can see, the comparison of the wearing capacity of steel with its quality is strictly a fair one.

Again, in the course of this discussion—not a few times—the exceptional cases, the cases where individual rails did not conform to the general law, have been taken out and held up prominently before us, as though these individual and exceptional cases were the only thing we should consider. Now, I submit to you that this is simply trying to overthrow a law by the exceptions to it, or, in other words, to nullify the teachings of a large number of samples by the teachings of a few exceptional cases, and I submit still further that this method of proceeding is neither good logic, nor fair, sound deduction.

I must not omit to comment on the remarks of those speakers who have refuted conclusions which I did not advance, and have then considered my position, namely, that the softer rails give the better wear, as completely demolished. A notable case of this kind is Mr. Kent, who because he does not find that there is a direct relation between the loss of metal and the carbon, phosphorus, silicon, or manganese, or phosphorus units in this series of rails, affirms that I have not solved the whole problem of wear, and, *ergo*, the softer rails do not give the better wear. I beg to remind him that I have never said that I had solved the problem of wear. I ex-

pressly say I have not solved it, but I do not see how that affects the main question; nor do I see, because there is no direct relation between carbon and loss of metal, that it is impossible for me to take a series of rails which have been in service and find by a study of them what chemical composition and what physical properties are, in general, characteristic of those rails which have given the best service. This I claim to have done, and the conclusion seems to me so plain that he who runs may read, namely, that the softer rails give the better wear.

With regard to Mr. Metcalf and his attributing all the troubles of steel to nitrogen, I think it may fairly be said, first, that Mr. Metcalf brings no proof to show that nitrogen is the bane of steel; and second, if it is, the natural conclusion would be that no steel could be made except by the crucible process, which would undoubtedly be a satisfactory conclusion for crucible steelmakers, like Mr. Metcalf, but would hardly satisfy the stockholders of the Bessemer works, or stop their making steel with nitrogen in it in the future. With regard to another criticism of Mr. Metcalf's, that the question of flow had not been considered, I would say that I think there is very little evidence of flow in this series of rails anyway. And so I asked Mr. Metcalf how the flow influenced the loss of metal by wear. He replied that flow squeezes the metal toward the flange and then the flange rubs it off. To this I made reply, that the flow, whatever there is of it, must be away from the forces which produce it. Now, both the pressure of the flange against the rail and the coning of the wheels would cause the metal to flow away from the flanges instead of toward them, and consequently I do not see how you are going to get metal there for the flange to rub off. The flow must be in the other direction, or away from the flanges. Although a few of the rails in this series give evidence of having a little metal pushed off out of place by reason of flow, yet the metal is there. It is not worn off, and the question we are studying is loss of metal by wear.

One or two points further, and I am done. It has been said, "You have not exhausted the question yet. More study must be put upon it." No one is more conscious of the truth of these statements than I. I do not pretend to have exhausted the question. I wish there were fifty workers in this field. But I believe that the results that we are discussing are the best information that we now have upon the question of the relation between the wearing capacity of steel and its chemistry and physics. I would not at all affirm

that this will be the best information on the subject five years from now. But I think that man does his life-work best who lives up to all the light that he has in his own time. And so I ask you to utilize this work, to act upon it, and guide your practice by it until something better is obtained.

Finally, I have been accused of trying to teach the steelmakers how to make steel, and it is to be supposed that they know already much more about that point than I do. Now, if any one thinks that such has been my aim, or has ever been in my thoughts, he has certainly misunderstood me. What I am striving for is to tell the steelmakers what we want, not how to supply this want. This whole question of the fitness of material for the purposes for which it is intended is in its infancy. We are doing something toward studying it at Altoona. The principle which governs us there is that the kind of service that is to be required of the metal must determine what kind of metal shall be used. Because softer steel gives better rails, we do not think softer steel will give better crank-pins. In crank-pins we require stiffness, which comes with harder steel. But in rails, in tires, in bridge rods, and in boiler plate we are, so far as our knowledge now goes, inclined toward soft steel. And all the information which we have thus far been able to accumulate in regard to these kinds of service confirms our position and justifies our conclusion.

And now, how can the best results be obtained in trying to decide upon the qualtity of material best fitted for any kind of service? I do not see that the steelmakers can study this question alone, for after the steel leaves their hands they know very little of its behavior. It does not come under their personal observation and study. It seems to me, therefore, that the question can only be studied by both the consumer and the producer working together. I cannot but regard that the interests of the consumer and the producer in this matter are one, that neither can solve the question alone, and so I ask you to work with, rather than oppose me, to utilize the information that is gained, so far as it is gained, and to constantly hold in mind the necessary dependence of both producer and consumer upon each other.

DISCUSSION ON STEEL RAILS.

HELD AT THE VIRGINIA MEETING, MAY, 1881.*

C. P. SANDBERG, LONDON, ENG.:† I think we should all be grateful to the Pennsylvania Railroad Company, and to their chemist, Dr. Dudley, for spending so much time and money in order to solve an important question; nor are we less indebted to the public spirit which leads them to impart the experience thus gained. In Europe nothing similar has hitherto been done, either by a company or by any private individual. In England the great railway companies employ their engineers in other ways, and do not keep a chemist or specialist to study rails; but even if they did they would probably not publish the results. The chief professional engineers are so occupied with their private practice of railroad construction generally, that they cannot be expected to devote their time and energies to so special a question. The German Railway Union has, in my opinion, missed the real object of its elaborate researches by falling into the error of specifying costly, impracticable tests for rails—tests at the same time which do not infallibly expose the impurities that may be in the rails under examination. There has, therefore, been nothing done on this side of the Atlantic in the way of exhaustive study to determine the best composition for steel rails. America should consequently have full credit for the enlightened example which she has set.

I wish, however, to make a few remarks on Dr. Dudley's second paper,—a paper which follows very much upon the same lines of argument as the first read three years ago, upon which I have previously touched in my paper on the same subject read at the meeting in August last. If Dr. Dudley had discovered a new metal he could hardly, I think, have taken more pains to prove that he was correct in his first formula for the best chemical composition of steel rails. But I have seen so much done in the way of proof by experiment that I am inclined to think that almost anything can be proved by experiments and by samples. If Dr. Dudley would only give up his formula, which would not suit any country—not even America—

* For the convenience of members it has been thought best to insert the continuation of this discussion at the Virginia meeting in this place, rather than to delay its permanent publication until the issue of Volume X, *Transactions*, where it would properly belong. T. M. D., Sec'y.

† Sent to the secretary in manuscript.

to work by the ordinary Bessemer process, and would content himself with applying such chemical tests in association with mechanical or physical tests, as are practically workable, with a view to arrive at something better in rails generally, he would, I think, have done his company and society at large even better service than he has so far rendered. As it is, he seems to have the American makers arrayed against him, nor will the European makers, I fear, sympathize with him greatly. No one can, however, deny that Dr. Dudley has carefully worked out a series of experiments, sparing no pains to substantiate his views. Still it by no means follows that his conclusions are correct, and, as has often happened before, doctors may honestly disagree as to the best means of arriving at the truth.

As to the discussion at the Philadelphia meeting, it is to be regretted that it chiefly represents one side, viz., the makers; for the engineers do not seem to have been well represented on this occasion. If they had been better represented the general conclusion would no doubt have been different. Some of them would probably have agreed with Dr. Dudley in many respects where the makers were against him; for instance, they would have held that copper and sulphur are of more importance to the producer, and, therefore, the consumer can safely leave them out of the question without personal detriment.

But for blooms it will be necessary, at least occasionally, to determine the sulphur so as to detect red shortness which might otherwise cause cracks and wasters in rolling out the English blooms in America. This would be particularly the case if the mills used for that purpose had low speed so as to prevent the steel being worked out at a good heat. As for copper, an excess is more rarely the case; moreover, a larger amount may be tolerated than in the case of sulphur, so that this determination is not of such importance as that of the sulphur. In the basic process the sulphur is of very great moment, inasmuch as the ordinary white pig iron generally contains a greater amount of this impurity than does the Bessemer pig iron. It is, however, to be hoped that by increased experience makers will succeed in the elimination of sulphur as well as they have done with the phosphorus. Anyhow, sulphur will always be a source of trouble to the maker rather than to the consumer of rails.

The carbon test by coloration according to Eggertz's method is quite reliable within any limits that occur in rail-steel. It is true that it does not show the graphite, but the amount of this is so

small that it can be left out without any detriment in practice. Besides, this method is very generally adopted, and where the make is large and every charge has to be tested, the number of tests may amount to about one hundred a day. How could this be done if combustion tests were used? Moreover, I should mention that Professor Eggertz has lately introduced considerable improvements, by which greater accuracy can be obtained even when the carbon is very low.

No one has a right to doubt the correctness of analytical results made by Dr. Dudley's assistant as long as he certifies to them. But the makers have, no doubt, some right to complain of the small amount of silicon allowed in Dr. Dudley's formula, viz., .04 per cent. What would Dr. Dudley say, if on analyzing some steel rails from his own road, which had given very good results, he had found ten times as much silicon as his formula required—a result which I think quite possible, as I have sometimes found this amount of silicon in steel of excellent physical characters. There is no impurity in steel rails which varies so much as the silicon, not only in different districts and countries, but even in the same works. It often varies four or five times as much at one time as at another, the variation depending chiefly upon the heat of the blow the pig iron used being the same. Silicon passes away simultaneously with the carbon in the cold blow, but keeps in almost undiminished quantity in the hot blow; and the makers have as yet no means of determining when the silicon is removed, as they have, for instance, in the case of carbon. The use of the spectroscope has been of but little value in practice on a large scale. It would therefore be very hard—in fact, unnecessarily severe—to limit this impurity to such a degree as to be scarcely attainable in practice.

I fear also that Dr. Dudley's physical tests are quite as impracticable as his chemical ones. To apply a bending, or a shearing, or torsion test to an article which has in daily use to sustain concussion and abrasion, seems a curious course of procedure. Besides, these tests are too slow and costly to be of much service in actual practice, just as is the case with the tests of tensile strength and contraction of area stipulated by the German Railway Union.

I have had ample experience of late to prove the comparative worthlessness of such tests in Germany, and I should regret to see America or any other country adopt them. For years these tests have been insisted on by the German Railway Union for all its rails; the drop test has been so reduced as to have little or no effect,

and even in some cases it has been abolished altogether. Since I commenced inspection at German works, not only have I found some makers objecting to my heavy drop test, but on analyzing the German rail-steel I have found that it contains twice as much phosphorus and silicon as the English rail-steel, where the drop test has principally been used for many years. In fact, the scientific German tests, with all their disadvantages of slowness and expense, have proved altogether less efficacious in keeping out these impurities than the simple drop test, although the latter is designated as "crude." Still Dr. Dudley recommends the former when he cannot put in execution the still-born idea of a registering manometer on the punching machine for measuring the hardness of the metal, as suggested at Barrow many years ago, but never actually put into practice. Why should we give up a test that has for years done good service for millions of tons, simply because it is "crude," and adopt a slow, costly, and impracticable one, which has not done good service, simply because it is "scientific?"

As to the theory of the softest rail being best for wear, I should require further proof on thousands of tons before positively accepting it. If the Pennsylvania Railroad Company and Dr. Dudley will, as we hope, continue their researches on steel rails, not only for their own benefit but also for the good of mankind, I would venture to suggest that instead of repeating for the third time these costly and elaborate, not to say tedious experiments, they should lay a thousand tons of soft rails made to Dr. Dudley's formula and proposed physical test, and also, on the same line of road opposite, another thousand tons of hard rails with the ordinary chemical composition, inspected as I have described, so as to compare the results of wear with the view of proving which is the best. This would cost little or nothing, and after all be more convincing than any experiments, however carefully made, on single bars, such as those now executed with so much care. The only drawback to my suggestion is the time it would require for the comparison, this time depending upon the amount of traffic on the line where they are put down. Meanwhile some approximate results from single rails could be obtained, as to the wearing resistance of soft and hard rails, and the hardness derived either from carbon, phosphorus, or silicon, if a locomotive engine were placed on such experimental rails, one being soft and one hard; it should have its driving-wheels sliding on the same spot, water and sand being applied, and the cutting or wear in the two rail-heads could be measured, or the reduction of weight ascertained. This

mode would have the advantage of giving results in a day or two, but I admit that it would be but a crude test of single bars.

Ten years ago a paper was read at the Institution of Civil Engineers by Mr. Price, of Dublin, on a rail-testing machine very much like a turntable, which was revolved on experimental rails with high velocity, in order to ascertain the resistance against wear from rolling weight; but this machine never came to work, at least in London, where it was meant to establish it as a public testing-machine for rails. The best testing-machine is now the underground railway, where steel rails of a very heavy bull-headed section last but a few years; but it is doubtful whether the engineers in charge would allow it to be used for experiments, at least they have not done so yet. The best authority on this subject is Mr. R. Price Williams, M.I.C.E., who has read several papers, and collected data and statistics on the wearing resistance of the rails on English railways.

In the address to the meeting of the Iron and Steel Institute, which has been just held in London, the president, Mr. J. T. Smith, of Barrow, quotes Mr. Price Williams's experience of steel rails lasting nine times as long as iron rails, but adds that this is probably more often the exception than the rule; and the past president, Mr. Menelaus, thinks the endurance to be only three times that of iron rails. I have of late years adopted six times, but since the price of steel rails became reduced to that of iron no calculations are needed to show their preference. It is, however, certain that those steel rails from which such excellent results were obtained at first, say ten years ago, were made harder than they are now, and this seems rather to oppose Dr. Dudley's new theory that the softest rail lasts the longest.

An alteration of importance in the second paper is that the Doctor in his third test has adopted the use of crop ends, although he still adheres to bending tests instead of drop tests for the sake of securing a soft material. But the drop test would also secure a soft material if prescribed to a minimum deflection for a certain blow given; and at the same time it is a criterion of safety. I have stated that as an effect of my standard drop tests, the deflection should amount to 3 inches or 4 inches according to the hardness of the steel and height of section. I admit that the difference in the foundation, as to solidity, might be misleading, but at any rate it is good enough for comparative tests made in the same place and for the same section; besides it has the advantage over the proposed mode of cutting out the test-piece

from the rail and bending in the machine, a test which is too slow and costly to be used in daily practice.

With a view of securing soft material for rails the basic process comes in most beautifully; by this process they can be made as soft as lead and with only a trace of silicon, and still the ingots are made solid, no doubt for the reason that the basic steel is cast so much hotter than the Bessemer.

In fact the difficulty by this process was at first to make steel of ordinary hardness; but now, since hematite pig is added instead of spiegel, steel of any degree of hardness can be produced. Indeed I am just now inspecting blooms made by this process, and judging from several analyses made, I have found the average contents as follows: silicon only a trace, carbon, average, 0.33, manganese 0.35, and phosphorus 0.08. Such rails, tested to my standard drop test, show a deflection of about 5 inches, which indicates more softness than ordinary rail-steel made by the Bessemer process. The safety from breakage secured by the soft metal is decidedly an advantage to the engineer, but not exactly so to the railmaker, since the softer metal necessarily gives more cracks and wasters than steel of medium hardness.

Having been the inspector to the Swedish government railways for the last twenty years, I have been naturally anxious to secure to them a rail which should be safe against their rigorous climate, and fearing that the so-called phosphor-steel would break, I made, at the Panteg Works, in South Wales, six years ago, some special phosphor-steel rails (about one hundred rails, with the amount of 0.25 per cent. phosphorus, but low in carbon and silicon), and tested them to my standard drop test.

These rails have been down at Stockholm on a branch ever since: none of them have broken, although the cold sometimes reaches minus 30° F. I can also give the experience from the Swedish state railways, of other rails, with a composition of carbon, average, 0.20 to 0.30 per cent, phosphorus 0.06 to 0.12, and silicon 0.10 to 0.30 per cent. Out of 35,000 only four rails broke during the winter of 1880, and these breakages might be equally well caused by mechanical faults as by the chemical composition. However, it is of course safer for cold climates to have as little phosphorus as possible in the rails, and to secure hardness by the presence of carbon.

The results just given show how wide a variation in the composition can be tolerated, even for rails exposed to a most rigorous climate. I think we ought to be thankful to Dr. Dudley for having

raised the question of chemical composition, for, the more we go into the matter the more our views will be widened, and we shall be disposed to grant more liberal variations in the impurities than we should have done if we had not analyzed the metal. Before chemistry has enlightened our views, there will naturally be errors committed from "*trop de zèle*" on the part of the engineers. For instance, an eminent engineer, not long ago, rejected some steel rails because they contained 0.15 per cent. of silicon, although they were faultless in all respects.

Another question arises as to the wearing resistance and hardness derived from carbon alone, compared with that from phosphorus, silicon, or manganese, carbon being, in these cases, at a minimum. Whether the wearing resistance is the same or not, we know that safety is best secured by the carbon, and by a minimum amount of the other impurities, particularly in countries with cold climates. However, in other countries with mild climates, and where the ores are impure with phosphorus, millions of tons of rails have been made, and laid down on the track, which seem to answer well, both as to safety and wear, although the carbon must be low, with a rather high proportion of phosphorus. Since, by the discovery of the basic process, the phosphorus can be eliminated and the carbon added by using pure hematite pig, instead of spiegel, after the blow, there is an opening even for countries with a severe climate, and with impure ores, to produce good rail-steel with a minimum of phosphorus, and with hardness resulting from carbon, just as if the steel had been made originally from pure ores. I should also remark that the amount of manganese—0.35—given according to Dr. Dudley, might well be doubled as a means of lessening the other "deadly sins of impurities,"—to use Dr. Siemens's expression,—and also in order to facilitate rolling into clean rails.

I would sum up my remarks on Dr. Dudley's paper, by saying, that while I disagree with his tests, both chemical and physical, I nevertheless agree with him in the application of chemistry to steel inspection; but it must be used only in a practical way; and if I have, in my paper read before this Institute, shown any decided preference for mechanical tests, it is simply because they have, under ordinary circumstances, done good service, and proved quite sufficient in practice. I have also said "let the chemist help us, but not be our dictator." For my own part, I apply chemical, combined with mechanical tests, and I have, in that way, even carried out inspection under Dr. Dudley's specification where railway companies

insisted upon adopting it. Mechanical tests come first, and the drop test to my standard is insisted upon for both rails and blooms (sample blooms are rolled into rails for the purpose of being tested); borings are then taken from the steel actually tested mechanically, and sent to my laboratory, where the carbon, phosphorus, silicon, and manganese are determined.

However, I do not think it advisable to publish any particular formula, or maximum and minimum of composition, because we are really not yet in a position sufficiently assured to do so. I think the first step, in introducing chemistry into rail and bloom inspection, is to institute a combination and comparison between chemical and mechanical tests. After sufficient experience and reliable data have been obtained, the time will have arrived when exact formulas may be established.

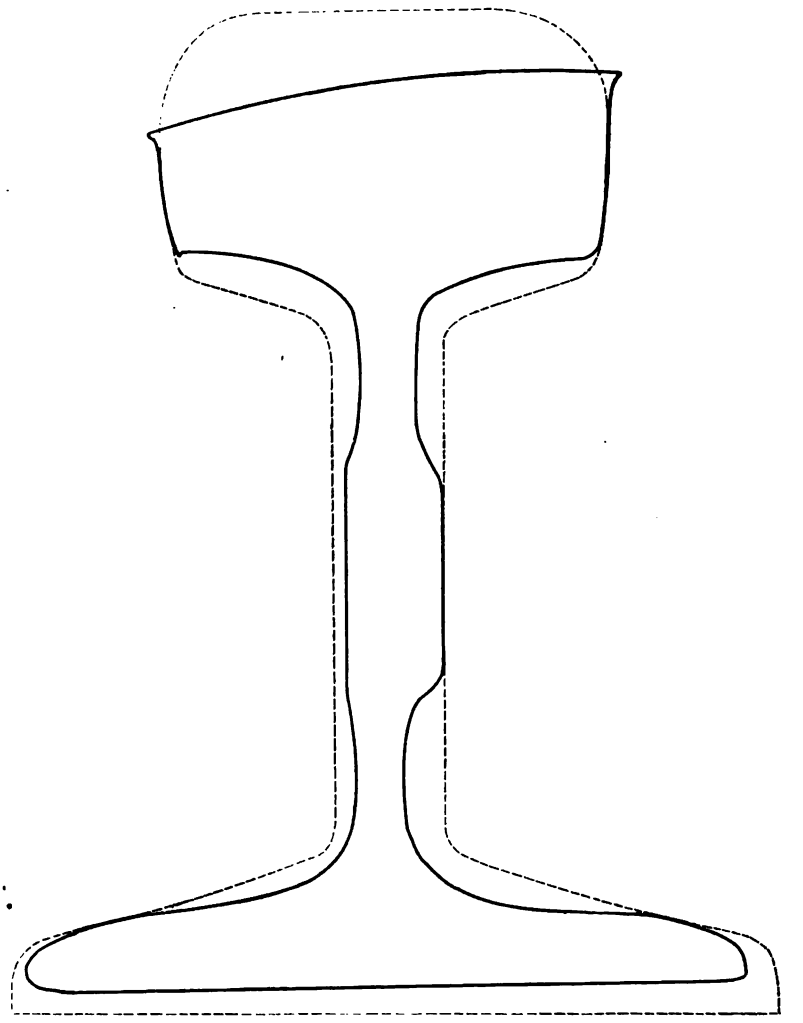
In the inspection of rails I only analyze when the mechanical test gives any extraordinary results. If, for instance, a rail has broken, under the falling test, if it has broken on the road under service, if it bends differently, showing differing degrees of hardness, then the chemical analyses are of interest, and may be of service. After all, however, it is only a large number of trials that should count, and no decided judgment should be formed from single observations. Chemistry has been very useful to the maker, and may be equally so to the engineer when properly applied; but no positive deductions should be made except after large and varied experience and experiments.

I think I have shown that as a professional inspector, I have, at any rate, done my part towards introducing chemistry into my practice wherever railway companies and my clients specify such tests. For their own sakes, as well as for the solution of many questions now under discussion, it is to be hoped that purchasers, without specifying too much, will rather proceed by degrees to adopt chemical inspection of their rails and blooms, in order to avoid unnecessary conflict. The engineers should never lose sight of the fact that the solution of such a question as this would be arrived at much more safely, and much better, with the assistance of the makers, and, therefore, it is not expedient to vexatiously oppose them. On the other hand, the makers should bear in mind that they cannot have it all their own way, and I may safely say that they have *not* got it in Europe.

I agree, without reservation, with the views which my friend, Mr. A. L. Holley, has expressed in his paper on "Rail Patterns;" and I can prove, by the contents of my circulars and by the cor-

respondence in technical papers, which has from time to time taken place, that the opinions I held when I took up the question of standard or normal patterns have remained unchanged, and are identical with those referred to above. It is, however, evident that

FIG. 1.



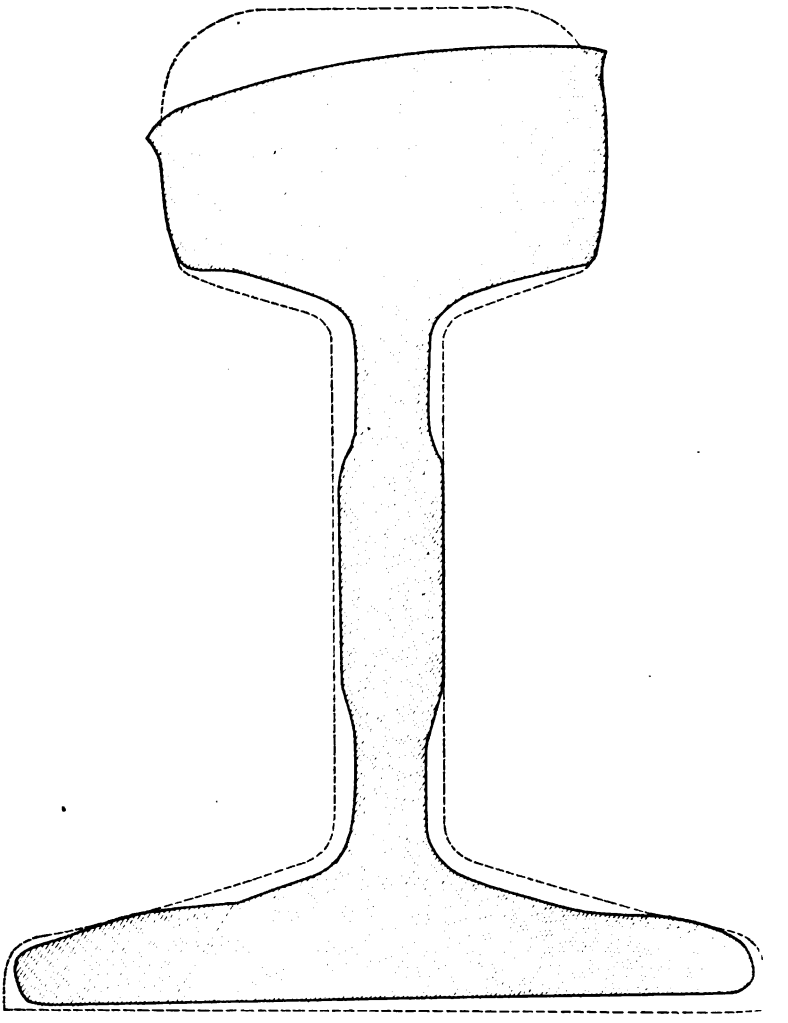
End View.

occasional remarks on the subject, published here and there in various ways, are not so valuable and serviceable as when collected and issued in a complete and concise form, and it is such a work of

reference on the subject of rail patterns that is now available in Mr. Holley's paper.

Rail making is a comparatively new branch of the iron and steel industry, yet it is of great importance, and railmakers have ever

FIG. 2.



Section beyond the Second Bolt Hole.

inducement to improve their machinery, so that in course of time more difficult sections will be rolled with ease, until ultimately, perhaps, a thinness will be obtained comparable to a spider's web.

On the other hand, just to show that there is some "body" re-

quired even for the flange and web of the rail to resist the wear and tear at the joint, particularly if it is loose, I show a lithograph drawing of a steel rail after eight years' service on one of the best maintained railways in Germany. (See accompanying cuts.)

But it necessarily follows that, with this progression, normal forms and patterns will only be retained as standards for periods of greater or less duration; and it will become a question for the consideration of the railway engineer, whether it would be more advisable to retain and alter what he has, or to put up with the inconvenience of keeping several patterns and having new fish-plates. In the construction of new lines one can choose the most modern and economical section, only limited by the price at which it can be obtained. Under these circumstances, it is evident that no patterns will be universally adopted for ever, notwithstanding the vast amount which would be saved if they could possibly be definitely fixed. It is curious to remark that the very man who now proposes to finally settle upon a standard is, probably, the one who by his genius, aided by the immense resources of the United States, will produce patterns and sections more desirable than those which he would now like to make permanent, and will thus bring about the very changes which he now deprecates.

I willingly admit that, considering the present stage of excellence to which rail making has attained, my pattern appears "clumsy" alongside of the more difficult one of Mr. Holley's. In 1870 I first designed my pattern in accordance with what English railmakers could then produce, and with the restriction, that no extra cost was to be incurred in manufacture. In 1878 I found that the mills were so far advanced that there was a decided call for a second series of patterns, and it was not to be expected that either of these series should be equal to the Holley pattern, recently designed, with respect to the flanges and web. The difference is merely an illustration of the progress which has meanwhile been made.

Mr. Holley's new patterns are produced after the vast experience gained by him in his visits to rail makers in Europe for newly-designed and constructed works in America. It may be remarked here that the European mills have much improved of late. New mills have been laid out in England, partly on the reversing system, and on the Continent the improvement is marked by the use of three high rolls.

With reference to Mr. A. Welch's remark and also Mr. Hart's letter, about the first original section for steel rails designed as early

as 1866, I wish to assure both these gentlemen that I had not seen the section when I designed mine, and even if I had, I should not have then dared to put it forth as a standard for English railmakers; and the soundness of my opinion has a simple but conclusive proof in the statement made concerning the extra price which was at that time required for their production. I need not say that I highly approve of the original Welch section, for it is in principle similar to the design which I made fifteen years subsequently; and from a professional point of view I would fully concede to Mr. Welch the credit of first designing the modern steel-rail section. From a commercial, matter of fact, and practical point of view, he was, however, before his time by many years; or to put it in another way, rail making was ten years behind its time when the new metal steel was first introduced for rails.

If his design has been incorrectly identified with my name (as the sections are similar in principle, though they differ in thickness of flange and web), I beg to say (1st) that I much regret the misunderstanding which has arisen through no fault of mine, and (2d) that no confusion has been intentionally created by me.

It is a pity that the section designed so long ago has not been made public at an earlier date, as it would make a really good standard pattern, and even now be quite equal to present requirements.

In conclusion, I wish to say that I have never desired to claim any invention or novelty by the publication of my sections; they were put forth as being such as English railmakers could and would produce at the ordinary market price, and as being the best and most suitable to be so obtained. Had Mr. Welch or Mr. Holley put forward theirs ten or fifteen years ago, I should have been the first to recommend them. In fact I should have been glad to see their names associated with rail patterns in their own country, in the same way as mine has been.

PROFESSOR RICH. AKERMAN, STOCKHOLM, SWEDEN:* I agree with your (Mr. Sandberg's) views that it is too early yet to stipulate only one definite chemical composition in the rails. Such a stipulation, I think, might be justified, if it were not for the manganese; but this metal changes the properties of the iron and steel in the same direction as carbon, silicon, and phosphorus, by increasing its tensile strength, stiffness, hardness, and brittleness. If the iron and steel does not only contain carbon and manganese but also phosphorus,

* From a letter to Mr. Sandberg.

silicon, and sulphur, I think everybody will agree that the manganese, to a great extent, can neutralize not only the effect to red-shortness, caused by the sulphur, but also the tendency of the iron or steel to become burnt and brittle, caused by the phosphorus and silicon. Thus brittleness can be as well increased as decreased by the presence of manganese, and I, therefore, consider that, however necessary analyses now and then may be, in order to enlighten us and to explain exceptional cases, yet they are not convenient as practical tests upon rails, especially as the properties of the rails not only depend on the chemical composition of the iron or steel, but to a great extent also upon the soundness of the ingots and the mode of manufacture.

Still less necessary than analyses I regard the German system of controlling the rails by researches on contraction of area. I do not consider either the elongation or the contraction of area, in fracturing samples, to test tensile strength, to give a correct idea of the toughness of iron or steel. On the contrary, I regard the falling test, properly carried out, to be much better in this respect and to give a greater safety against breakage than the common tests on tensile strength.

DR. R. W. RAYMOND, NEW YORK: It occurred to me after the presentation of Dr. Dudley's interesting paper on this subject, and after the discussion to which it gave rise, that the important data he had collected might be made, by suitable mathematical treatment, to yield more significant indications than had yet been obtained from them. It is true that Mr. Cloud has discussed by the method of least squares, the results set forth in Dr. Dudley's former paper, on the breakage of rails. But the breakage of a rail is, I think, far more likely to be due to mechanical or accidental (not chemical) conditions than the loss of metal by wear. For this reason I should attach less importance to the data, and place less reliance in their discussion. Moreover, the number of observations in the paper referred to was relatively small—too small to permit the method of least squares to give trustworthy results. Finally Mr. Cloud correlated the chemical constitution with certain physical tests, not directly expressive of the resistance of the rail to breakage. In the case before us, we have sixty-four observations, and they directly connect certain chemical proportions with a definite physical result of experience, namely, the loss of metal by wear. I think, therefore, that this case presents a better opportunity for such a mathematical discussion as will test,

to some extent, the assumptions underlying Dr. Dudley's conclusions.

These assumptions are: that the loss of metal per million tons of traffic, depends, first upon the circumstances under which the rail is worn; secondly, upon the proportions of its various constituents, and that the amount of loss is affected by each constituent in a certain ratio, so that if the circumstances were the same for all the rails, the wear per million tons might be approximately expressed by an equation of the form $I + Cc + Pp + Ss + Mm = R$, in which I is an unknown value, depending on the quantity of iron (and other ingredients not determined) in the rail, and assumed to be constant for all the rails; c, p, s, and m are the experimentally determined quantities of carbon, phosphorus, sulphur, and manganese, as tabulated in Plates VI and VII of Dr. Dudley's paper; and R is the experimentally determined wear per million tons; while C, P, S, and M are unknown coefficients. In other words, it is assumed that the difference in wear is proportional to a difference in c, p, s, or m, and that the effects of a change in the amount of either are independent of the amount of the rest—within the experimental limits of the problem.

It is also assumed that sulphur, copper, and other ingredients, not determined, are equally present in all the rails, or at least do not affect the wear, since I is taken as constant.

Dr. Dudley tacitly assumes the coefficients C, P, S, and M to be positive; and assigns certain values to them, by means of which he reduces the equation to the form $I + Px = R$, x being equal to $\frac{Cc + Ss + Mm + Pp}{P}$, or the number of so-called phosphorus units in the rail.

But we do not have R directly given under constant circumstances. The varying weights (per engine, car, or train) and the varying speeds, we must neglect for lack of data, and assume that in these respects the rails examined have been treated substantially alike. But there remain the varying conditions as to track, which must be eliminated. Dr. Dudley gives six classes, four of which contain 8 rails each, and two 16 rails each. Beginning with the first (tangent grade), we take the mean of the figures expressing wear for that class; and continuing this process through the other five, we obtain six expressions in quantity of loss by wear, which we assume to represent, in their differences, the varying conditions of the track, with respect to grade and direction. We now take the mean of these means (giving double weight to the groups containing 16 observations). This general mean is the loss of metal per million tons of traffic for a rail of average constitution under mean circumstances.

The difference between it and the mean for any one group is a constant correction to be applied to the tabular wear of each rail in that group, to obtain what may be called the reduced loss for that rail; that is to say, an expression for the loss per million tons of traffic which that rail would have shown, had it been worn under average circumstances. For example (the tabular numbers being multiplied by 1000, to get rid of long decimals), the general mean of loss is 76.7; the mean for the tangent-grade group is 70.1; the correction is + 6.6; the experimentally determined loss of rail 887 (of that group) is 38.6; and the reduced loss, 45.2.

I had at first intended to do with the units of wear what Dr. Dudley did with his chemical units—reduce them all to one actual group. As he obtained phosphorus units, so we might obtain tangent-grade, or grade-curve, or level-curve units. But the reduction to an ideal average unit of wear is preferable, as giving the smallest possible average corrections, and distributing the errors involved in the corrections uniformly over all the observed cases, instead of concentrating them on a part. I am indebted for this suggestion, and for the larger part of the voluminous calculations required in the details of the work, to a mathematical friend, without whose aid I should scarcely have been able, in the scanty intervals of other absorbing occupations, to solve the problem, even after stating it.

It is, however, simple enough, though very tedious. From the 64 given cases, we form 64 equations of condition, of the form $I + Cc + Pp + Ss + Mm = R$, in which the different symbols have the same meaning as before, except that R is the reduced loss by wear, as already explained.

These 64 conditional equations are now, by the method of least squares, reduced to 5 normal equations, containing the 5 unknown quantities, I, C, P, S, and M. The solution of these equations will give us the most probable values for I, C, P, S, and M, which the equations of condition can yield.

I do not intend at this time to publish the details of the calculation. If time permits, there are other assumptions which I should like to introduce into the discussion, to test the results already obtained. It would be interesting, for instance, to repeat the whole process with equations of the form $I \times Cc \times Pp \times Ss \times Mm = R$.

At all events I am not now prepared to present the figures of the calculation, in which, though the equations have been solved, the probable errors of the solutions have not yet all been determined. But I am able to say that Dr. Dudley's own data and assumptions, thus treated, show the coefficient of silicon to be negative, and that

of manganese to be practically zero. In other words, the silicon, though a "hardener," does not, like carbon and phosphorus, increase, within the limits of these tests, the loss of metal by wear; on the contrary, it increases the wearing capacity. And manganese seems to be neutral in that respect, behaving like so much iron. These two metals play, then, a very different part from that assigned to them in Dr. Dudley's formula, which holds true (and that with modified coefficients) for the non-metals, carbon and phosphorus only.

I will not here enlarge upon the imperfections inherent in the application of the method of least squares, and in the necessary employment of so many assumptions. In spite of them all, I believe that the indications here afforded are significant. Certainly the "phosphorus-unit" system must be abandoned, so far as silicon and manganese are concerned; but are there not hints of practice pointing in the same direction, as the results of this mathematical inquiry, as to those two elements? Have we not heard repeatedly of high-silicon rails showing extraordinary wear? And is it not "important if true" that manganese may be increased beyond Dr. Dudley's limit, if it be otherwise useful or convenient, without injury to the wearing capacity?

DR. C. B. DUDLEY said that he had listened with much interest to the present discussion, but he was not prepared to reply at the moment, to all that had been said in criticism of his paper read at the Philadelphia meeting. At a subsequent meeting, after he had had opportunity to carefully examine and study the remarks of the different contributors to the discussion, he would briefly sum up the case from his standpoint.

MEMORANDA ON THE ANALYSIS OF STATISTICS.

BY A. W. HALE, NEW YORK CITY.

IN a work published in 1838, De Morgan, the author of the article on "Probabilities," in the *Encyclopædia Metropolitana*, says: "The method of least squares is not yet introduced into the affairs of common life, ... that many things which are demonstrable only by the higher branches of mathematics are looked upon as useless." And he mentions an instance in which "a method was suggested for estimating the relative importance of boroughs, by considering their population and contributions to the revenue com-

binedly, which was ridiculed by some members of the House, partly because a more simple, but wrong method happened to give nearly the same results, and partly because it involved decimal fractions."

If this may seem to imply ignorance or prejudice on the part of British legislators, there is something to be said on the other side, for De Morgan himself elsewhere says: "My own impression, derived from many circumstances connected with the analysis of probabilities, is, that mathematical results have outrun their interpretation; and that some simple explanation of the force and meaning of La Place's celebrated integral will one day be found, ... which will at once render useless all the works hitherto written." That is to say, there may be some foundation for an instinctive prejudice against the application of such complicated reasoning to relations which are apparently simple.

Quetelet, in 1846, wrote his letters on probabilities with illustrations of the application of the method of least squares, which approaches, perhaps, as nearly to a popular treatise on the subject as anything which has yet been published. Professor Chauvenet, in 1864, published, as an appendix to his astronomy, a treatise on the subject, which has been the textbook in this country; but its use has been confined principally to astronomical and geodetic computations. Professor Merriman, in 1877, published a treatise on the method of least squares, which, by separating the theory and the practice, has probably considerably enlarged the application. He gives the titles of forty-seven, selected from a list of four hundred works on the subject, running from 1714 to 1873, the greater part of which are occupied with the discussion of the theory, and are little known and read. The subject, in fact, belongs to, perhaps, the most intangible and least attractive branch of mathematics. But if the theory of it, like that of the calculus, borders on the metaphysical, the results are useful tools, which can be used with the utmost confidence.

At the meeting of the Institute in August, 1880, Professor Munroe read a paper in which he brought the method of least squares to bear upon the study of the statistics of the working of stamps in the Western States and Territories, furnished by Dr. Raymond in 1870, and brought out their true meaning and essence. This paper is interesting, not only on account of the ability with which the subject is treated, but also on account of its novelty, or as I should say, rarity, for Professor Chase, for example, has made many interesting analyses of meteorological tables by a similar

method; but this is perhaps more nearly what De Morgan calls introduction "into the affairs of common life," and shows that some advance has been made since 1838.

The business of mining and milling is so largely empirical that the greater part of what there is of science in it, lies locked up in such statistics. There has never been so large a field, as in this country, for the production, nor so much activity, as at the present time, in the collection, of data relating to this subject, but the discussion of such statistics has evidently not kept pace with their accumulation. There is an immense amount of material ready for treatment, but the requisite implements, which are simple formulas stripped of theory and mathematical complications and confusion, are not generally accessible, and they have not yet found their way into the engineer's pocket-book where they may with advantage be put.

The suggestion has been made in the journal of the Statistical Society, that if they who furnish statistics for publication would work out their significance, and suppress all such figures as are not significant, the gain would be large. In the present paper I have written out a few formulas that I have had occasion at one time or another to work out, simplify, or rearrange, which tend to facilitate this kind of work. I have done this in the hope that others may be induced to extend the list.

The general statement is this: We have a table of statistics which we will assume are direct observations. The table is inaccurate, defective, incomplete, rough, irregular, and the law of its structure is unknown.

1. *The Table is Inaccurate.*—There are one or more observations which, through some accidental error, depart so far from the mean that they should or may be rejected.

Peirce's criterion for the rejection of doubtful observations is intended to apply to a case of this kind.

The principle involved in Professor Peirce's discussion of the problem is, as stated by himself, "that the proposed observation should be rejected when the probability of the system of errors obtained by retaining them, is less than that of the system of errors obtained by their rejection, multiplied by the probability of making so many, and no more, abnormal observations."

The mathematical analysis of the problem is intricate, and the problem has led to much discussion, some mathematicians maintaining upon good grounds that no observation should be rejected. But observations have been and will be rejected when the judgment approves their rejection. The measure by which the judgment

is likely to determine the rejection or retention of observations is the direct ratio of the errors, which is not the law of "facility of error." The unaided judgment is likely to reject observations which should be retained rather than the reverse. The question is not altogether whether we have a rigidly accurate criterion, but whether we have a rule which is easily applied and which is more to be trusted than the judgment alone. This requirement Peirce's criterion appears to meet; and tables to facilitate its application have been prepared by Dr. B. A. Gould. By making a slight modification, the application of the criterion, especially when restricted to direct observations, is extremely easy.

The formula of Professor Peirce is a function of the "mean error." The modification which I make is to substitute for the mean error the more familiar idea, the average error, meaning by error the difference, disregarding signs, between an observation and the average of the observations. The "mean error" is strictly a function of the sum of the squares of the errors, and only approximately of the sum of the errors. Dr. Peters gives a formula which, when the number of observations is considerable, is a close approximation to the true expression.

Let n_1, n_2, etc., represent a series of observations,
n, the number of observations proposed to be rejected.
n_0, the average observation,
m, the number of observations,
v_1, v_2, etc , the several errors,
$[v]$, the sum of the errors,
v_0, the average error,
v_x, the limiting error,
ε, the mean error,
μ, the number of unknown quantities involved,
k^2, the tabular number from Dr. Gould's table,

Then $v_1 = n_0 \sim n_1$,

$v_2 = n_0 \sim n_2$,

$$v_0 = \frac{[v]}{m} \quad \ldots \quad (1),$$

(Chauvenet p 559),

$$v_x = k\,\varepsilon \quad \ldots \quad (2),$$

(Dr Peter's formula, Chauvenet, pp. 497, 521),

$$\varepsilon = \frac{1\ 2533\ [v]}{\sqrt{m\ (m-\mu)}} \quad \ldots \quad (3),$$

Combining equations (2) and (3),

$$v_x = \frac{1\ 2533\ k\ [v]}{\sqrt{m\ (m-\mu)}} = \frac{1.2533\ k\ m}{\sqrt{m\ (m-\mu)}} \cdot \frac{[v]}{m} \quad \ldots \quad (4),$$

Combining (1) and (4),

$$v_x = 1.2533 \sqrt{\frac{m\ k^2}{m-\mu}}\ v_0 \quad \ldots \quad (5),$$

Which is the formula for the limiting error which I have used.

That this approximate formula is practically admissible, the following consideration shows. The result obtained by the use of the less accurate formula will not be inaccurate unless the greatest error falls between the values obtained by the two formulas. It is possible to show by the calculus of probabilities that this is not likely to happen.

To facilitate the use of the foregoing formula (5), I have computed and given in the following table the values, to three places of decimals, of the quantity

$$1.2533\sqrt{\frac{m\,l^2}{m-\mu}}$$

for consecutive numbers of observations from 5* to 60, for one and for two unknown quantities, and for the rejection of one, two, and three observations.

m is the argument, and the tabular number, K, multiplied by l, gives the limiting error, an observation corresponding to an error greater than which is to be rejected. One observation having been rejected, the limiting error, v_x, for the rejection of two observations is obtained by multiplying the value for v_0, already found, by the tabular number, K for n = 2, in column 3, Table I. Two observations having been rejected, the limiting error for the rejection of a third observation is to be found in the same way.

v_x is made a function of v_0, rather than of $[v]$, for the reason that since the first order of differences is thus made more nearly constant the table admits more readily of condensation.

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* When $m = 3$, the criterion fails. When $m = 4$, the result by formula (5) may be indeterminate; $m = 5$ is, therefore, practically, the lower limit of the table.

TABLE I.

$v_x = Kv_o$.

m	$n=1$.			$n=2$.		
	1	2	3	1	2	3
	K	K	K	K	K	K
5	2.115	1.681	. . .	2.223	. . .	. . .
6	2.210	1 783	1.509	2.292	1 867	1.602
7	2.292	1.871	1 607	2.358	1.936	1.683
8	2 362	1 947	1.689	2.419	2.002	1.748
9	2 425	2.014	1.760	2.473	2.060	1.809
10	2 481	2.074	1.823	2 523	2 114	1.865
11	2 531	2 128	1 880	2.569	2.164	1.916
12	2.577	2.177	1.931	2.611	2 210	1.964
13	2.618	2.222	1 978	2 650	2.253	2 008
14	2 657	2.264	2 022	2 686	2 292	2 049
15	2.693	2.303	2.062	2 719	2.328	2.087
16	2.726	2.339	2.099	2.751	2.362	2.123
17	2.757	2.372	2.134	2.780	2.395	2 156
18	2.786	2 404	2 167	2 808	2 425	2.188
19	2.814	2 433	2 198	2.834	2 454	2.217
20	2.840	2 461	2.228	2.859	2 481	2 246
21	2.864	2.489	2.255	2.883	2 507	2 273
22	2.887	2.514	2 282	2 905	2.531	2.298
23	2.910	2.538	2.307	2.927	2.554	2.323
24	2 931	2 561	2 331	2 947	2 577	2.346
25	2.951	2.583	2 354	2 967	2.598	2 369
26	2.971	2.604	2 376	2.986	2 618	2.390
27	2.990	2.624	2 397	3 003	2.638	2.411
28	3 007	2.644	2 418	3.021	2.657	2.430
29	3 024	2 663	2.437	3.037	2.675	2 449
30	3.041	2.681	2.456	3.053	2.693	2.468
31	3.057	2.698	2 474	3.069	2.710	2.486
32	3.072	2 715	2.492	3.084	2.726	2 503
33	3.087	2.731	2.508	3.098	2.742	2.519
34	3 101	2.747	2.525	3.112	2 757	2.535
35	3.115	2.762	2 541	3.126	2 772	2.551
36	3.128	2.776	2.556	3 139	2.787	2.566
37	3 142	2.790	2 571	3.151	2 801	2.581
38	3.154	2.804	2.586	3 164	2.814	2.595
39	3.166	2.818	2 600	3.176	2.827	2.609
40	3.178	2.831	2.613	3.188	2.840	2.622
41	3.190	2.844	2.627	3.199	2.852	2.635
42	3.201	2.856	2.640	3.210	2.865	2.648
43	3.212	2 868	2 652	3 221	2.876	2 661
44	3.223	2 880	2 665	3.231	2.888	2.673
45	3.233	2.891	2.677	3 241	2 899	2 685
46	3.243	2.902	2 688	3 251	2 910	2 696
47	3.254	2 913	2.700	3 261	2.921	2.707
48	3 264	2.924	2.711	3.271	2.931	2.718
49	3.273	2.934	2.722	3.280	2.941	2.729
50	3.282	2.944	2 732	3 289	2.951	2.740
51	3.291	2 954	2.743	3 298	2.961	2.750
52	3.300	2.964	2.753	3 307	2.970	2.760
53	3.309	2.973	2 763	3.315	2.980	2.770
54	3.317	2 983	2.773	3.324	2 989	2.779
55	3.326	2 992	2.782	3.332	2.998	2 789
56	3.334	3.001	2.792	3.340	3.007	2.798
57	3 342	3 009	2.801	3.348	3.016	2.808
58	3.350	3 018	2.810	3.356	3.024	2 816
59	3 358	3.027	2 819	3.363	3 033	2.825
60	3 365	3.035	2 828	3.371	3.040	2.834

I have also computed a second more condensed table for one unknown quantity, the rejection of one observation, and with one decimal only.

TABLE II.

$$v_x = Kv_o$$

m	K	m	K
5	2 1	17	2.8
6	2.2	21	2.9
7	2.3	25	3 0
8	2 4	31	3.1
10	2 5	38	3 2
12	2 6	47	3.3
14	2.7	58	3 4

Professor Merriman gives, for the purpose of illustrating the method of determining the probable error, an example of twenty-four measurements of an angle, made at a United States Coast Survey Station.

A comparison of the results obtained by the application of the two formulas to these observations is shown by the following diagram:

5,19 — — Maximum error.
4,67 — — Limiting error by Table I.
4,58 — — Limiting error by Gould's table.
3,76 — — Next largest error.

Each formula rejects one and only one observation. And the result would be the same if the values for the limiting error obtained by the two formulas had differed much more widely.

The important point is, not so much that the interval between the limiting errors obtained by the two tables is small, as that the intervals between each and the adjacent errors are relatively large.

The facility with which the rule may be applied renders these tables useful, even where great accuracy is not required, by furnishing a ready and simple check upon the judgment as to the trustworthiness of observations, measurements, determinations in the laboratory, etc.

2. *The Table is Defective.*—That is, there is an observation wanting; or one has been rejected.

The conditions laid down in seeking a formula for replacing such missing observations are that it shall be

1. Simple, and expressed in ordinary algebraic language;
2. A function of consecutive observations only;
3. Rigidly accurate within certain assumed limits;
4. Such that the error introduced by accidental errors in the observations shall be, as far as practicable, a minimum.

The ordinary formula for interpolation evidently contains the solution. But in this case the interpolation is between consecutive terms, while in the case assumed it is between terms not consecutive.

This formula as given in Hackley's algebra is:

$$y = f + n\delta_1 + \frac{n(n-1)}{1.2}\delta_2 + \frac{n(n-1)(n-2)}{1.2.3}\delta_3 + \text{etc.} \quad (6)$$

in which

y = the interpolated term,
f = the first term,
n = the number of the consecutive term after the first,
$\delta_1, \delta_2, \delta_3$ = the first terms of the successive orders of differences.

Professor Hackley gives, as an example, the computation of the moon's latitude, in which the first three terms are used, and says that second differences will ordinarily insure sufficient accuracy.

Although for such applications as I have in view, I would evidently be justified in omitting terms involving a higher order of differences than the second, I have, for reasons which will be obvious, retained the third order of differences.

Putting

$$n_1, n_2, n_3, n_4, n_5, n_6, n_7 = \text{the observations},$$
$$f = n_1,$$
$$y = n_2,$$
$$\delta_1 = \text{the difference between } n_1 \text{ and } n_3,$$

(so that in equation (6) $n = \frac{1}{2}$ if a value for n_2 be wanted), and developing δ_2 and δ_3 in terms of the observations, we have

$$\delta_1 = n_3 - n_1,$$
$$\delta_2 = n_5 - n_3 - (n_3 - n_1),$$
$$\delta_3 = n_7 - n_5 - (n_5 - n_3) - \left\{ n_5 - n_3 - (n_3 - n_1) \right\}.$$

Substituting these values in equation (6) we get

$$n_2 = \frac{n_7 - 5n_5 + 15n_3 + 5n_1}{16} \quad \ldots (7),$$

which is an equation embracing seven and involving five observations, n_4 and n_6 being omitted.

Since n_6 is evidently symmetrical with n_2, the equation for the value of n_6 will be,

$$n_6 = \frac{n_1 - 5n_3 + 15n_5 + 5n_7}{16} \quad \ldots (8).$$

Combining equations (7) and (8), we get

$$n_3 = \frac{5n_5 - 2n_6 + 10n_2 - 3n_1}{10} \quad \ldots (9),$$

which is an equation embracing six and involving five observations, n_4 being omitted.

Since n_4 is *now* symmetrical with n_3,

$$n_4 = \frac{5n_2 - 2n_1 + 10n_3 - 3n_6}{10} \quad \ldots (10).$$

Combining (9) and (10), we get

$$n_3 = \frac{4(n_2 + n_4) - (n_1 + n_5)}{6} \quad \ldots (11),$$

which is an equation that evidently fulfils the first two conditions and is accurate for tables for which the third order of differences is constant.

For example, if we substitute for n_1, n_2, n_4, n_5, the cubes of 1, 2, 4, and 5, then, by equation (11), the cube of 3, n_3, = 27.

The equation also nearly fulfils the last condition above referred to. The error introduced by extraordinary errors in the observations will be least when the probable error of the average of the coefficients is a minimum. The mode of derivation of equation (11) gives rise to a number of incidental equations, involving different combinations of the observations, with different coefficients. The probable error of the average of the coefficients of equation (11) is not the least, but it is low; and, taking the other conditions into consideration, equation (11) is probably the best of the series.

3. *The Table is Incomplete.*—That is to say, it is not as full, not as long, as we would like to have it.

Transposing equation (11) we have

$$n_5 = 4(n_3 + n_4) - (6n_3 + n_1) \quad \ldots \quad (12).$$

By this equation one, and, in some instances, more than one, observation may be added at each end.

In equation (12), transposed so as to read $n_1 - 4n_2 + 6n_3 - 4n_4 + n_5 = 0$, the coefficients are the coefficients of the development of the binomial $(x - y)^4$. And the coefficients of the develop-

ment of any binomial $(x-y)^n$ may be substituted for it; that is to say, a new equation involving $n+1$ terms with the coefficients of the development of $(x-y)^n$ may be employed, though for the purpose for which it is intended equation (12) is probably the best. Thus from the development of $(x-y)^5$ we have

$$n_1 - 5n_2 + 10n_3 - 10n_4 + 5n_5 - n_6 = 0.$$
$$n_6 = n_1 + 5\left\{2n_3 + n_5 - (n_2 + 2n_4)\right\}$$

4. *The Table is Rough.*—That is, the probable error is large, or, in other words, the observations, generally, depart considerably from the mean.

Professor Airy has given a useful formula by which a table may be substituted for the original table, for which the probable error is less. By it, a new observation is calculated for each original observation by the following formula, putting the derived observation which is to be substituted for $n_4 = n_x$.

$$n_x = \frac{n_1 + 6n_2 + 15n_3 + 20n_4 + 15n_5 + 6n_6 + n_7}{64} \quad \ldots \quad (13).$$

The coefficients of the second member of equation (13) are the coefficients of the development of the binomial $\left(\frac{x+y}{2}\right)^6$; and, as above, the coefficients of the development of any binomial $\left(\frac{x+y}{2}\right)^{2n}$, may be substituted for it.

Thus, where n_x is the new value to be put in place of n_3,

$$n_x = \frac{n_1 + 4n_2 + 6n_3 + 4n_4 + n_5}{16} \quad \ldots \quad (14).$$

is a formula, somewhat easier of application than equation (13), and one that gives results which are nearly as good, although the probable error of the average of the coefficients is one-third greater. Thus, by comparing the results obtained by formulas (13) and (14), when applied to a table of thirty observations of barometric means at Philadelphia, given by Professor Chase, it was found that the probable error of the table calculated by equation (14) is 1.013 times the probable error of the table calculated by equation (13), a difference, in this instance, quite unimportant. By substituting for equations (11), (12), and (13), equations in which the coefficients are those of the development of a binomial with a lower or higher exponent, the resulting equations may not only be made a fraction of as many observations as may be desired, but they may be also made accurate

for a series of observations for which any given order of differences is constant.

5. *The Table is irregular;* that is, the intervals between the observations are not constant.

In the *Principia* (Book III., Lemma 5) Newton gives a problem for finding "a curve line of the parabolic kind, which shall pass through any given number of points," which contains the solution of the question. It is not easy to simplify Newton's statement; and I have retained, as nearly as possible, the form of his equations, making such modifications as are required to meet the case in point.

1. Newton gives the precaution to "observe well the signs." To eliminate this source of error somewhat, the observations are regarded as all positive, which for this purpose may always be done by changing the base.

2. The number of observations is limited to four, which is a sufficient number for a table in which the third order of differences is constant.

3. The interpolated observation is made a function of the average interval desired.

Put n_1, n_2, n_3, n_4 = the observations,

a_1, a_2, a_3 = intervals between observations,

a_0 = average interval desired,

$$\frac{n_1 - n_2}{a_1} = b_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

$$\frac{n_2 - n_3}{a_2} = b_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

$$\frac{n_3 - n_4}{a_3} = b_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

$$\frac{b_1 - b_2}{a_1 + a_2} = c_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

$$\frac{b_2 - b_3}{a_2 + a_3} = c_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

$$\frac{c_1 - c_2}{a_1 + a_2 + a_3} = d \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

$$a_0 (a_0 - a_1) = q \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

$$q (a_0 - (a_1 + a_2)) = r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

Then will $n_x = n_1 - a_0 b_1 + c_1 q - dr$, ... (23)

Where n_x is the term distant from the beginning of the series of four observations by the interval a_0.

Example: Suppose we take from a table of cubes the four terms $n_1 = 1$, $n_2 = 8$, $n_3 = 64$, $n_4 = 343$, and wish to find the value of the

term at a distance a_0 from the beginning of the series, for this special case where $a_1 = 1$, $a_2 = 2$, $a_3 = 3$, and $a_0 = 2$; then n^x by the above formulas = 27, as it should.

6. *The law of its structure is unknown.*

Professor Merriman has given a number of examples under this head.

The work of obtaining an expression for the law is partly empirical and partly analytical, and always laborious; empirical, because the form of the expression, being unknown, must be assumed. In general this is the most difficult part of the work. But since the majority of the questions which an engineer is called upon to discuss belong to one class of relations, and may in general be reduced to the expression for a conic section, the form of the equation will not be difficult to find, and the analytical part of the work for particular forms may be done once for all. What I have to offer under this head is simply an arrangement, with an illustration. Something like it is suggested by Gauss's method for the adjustment of equations, and by Kohlrausch.

TABLE III.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	. . . n
y	x	x^2	x^3	x^4	xy	x^2y		$\log y$	$x \log y$	$\phi(x, y)$	$\phi(x, y)$			
	Foo	tin	gs.											
		A	B	C	D	E	F	G		I	J	K	L	

TABLE IV.

1 Hypothetical Equations.	2 Final Equations, Functions of A, B, C, etc.
$Y = aX + bX^2$	$Y = \frac{(CD - BE)\,X + (AE - BD)\,X^2}{AC - B^2}$
$Y = a^x$	$Y = \log^{-1} \frac{H}{A}$

In Table III are put in column 1 the observations y, in column 2 the observations x, and in columns 3 to n various functions of x, y, and (x, y).

Calling the footings of these columns A, B, C, etc., in Table IV are put in column 1 the assumed equations, and in column 2 the equations, functions of A, B, C, etc., which will give the empirical formula directly.

The footings A, B, C, etc., will enter as factors in more than one equation in column 2, Table IV, so that, if an hypothesis fail, some of the work need not be repeated.

RECAPITULATION.

1. By the repeated application of equations (15) to (23) a table of observations, in which the intervals are constant, may be substituted for one in which they are not constant.

2. By Tables I or II an abnormal observation may be rejected.

3. By formulas (11) or (12) the rejected observation may be replaced by one which is a function of four consecutive adjacent observations.

4. By formula (12) the table may be extended.

5. By formulas (13) or (14) a table may be substituted for the given table in which the probable error is less; that is, the curve which gives the graphic representation of the observations may be smoothed.

After the application of this formula, formula (12), for extending the table, may be used with much confidence.

6. By substituting for formulas (11), (12), and (14), formulas in which the coefficients are the coefficients of some other binomial development, with the proper signs and divisors, the derived observation may be made a function of as many observations as may be desired, and true for a series for which any given order of differences is constant.

7. Tables III and IV may be made to contain all the data (given and derived) and formulas for obtaining the empirical formula for a set of observations directly.

SUPPLEMENT II. TO A CATALOGUE OF OFFICIAL REPORTS UPON GEOLOGICAL SURVEYS OF THE UNITED STATES AND TERRITORIES, AND OF BRITISH NORTH AMERICA.

BY FREDERICK PRIME, JR., PH.D.

IN this second supplementary list no titles to which an * is prefixed have been seen by the compiler; and he will be most thankful to have any omissions or inaccuracies in the list sent to him to be published as a third supplement in the next volume of the *Transactions*. The author is indebted to Prof. J. J. Stevenson, of New York, Prof. P. R. Uhler and John W. M. Lee, Esq., of Baltimore, and Lloyd P. Smith, Esq., of Philadelphia, for valuable assistance.

OFFICE, ALLENTOWN IRON COMPANY,
230 SOUTH THIRD STREET, PHILADELPHIA,
September 5th, 1881.

ALABAMA.

Geological Survey of Alabama. Report of Progress for 1879 and 1880, by Eugene A. Smith, State Geologist. Montgomery, 1881. 8vo., 158 pp., and 2 maps.

CALIFORNIA.

Omit Report of Hon. T. Butler King, in Supplement I.

For Trask's Geology and Industrial Resources, etc., in Supplement I., read Tyson's, etc.

Fremont's Memoir on Upper California, is also published as XXXth Congress, 1st Session. Senate Mis. Doc., No 148, and has a map.

For Randall's Report in Supplement I, read Report of the Special Committee in favor of a Geological Survey, submitted by Mr. Randall, April 24th, 1851. n.d., 1851. 8vo., 19 pp.

XXXIst Congress, 1st Session, Sen. Ex. Doc., No. 47, Part 2 [Part 1 is Tyson's Report.] Report of the Secretary of War in further compliance with the Resolution of the Senate, calling for Copies of

Reports on the Geology and Topography of California. Washington, 1850. 8vo., 32 pp. [Derby and Williamson.]

Geological Survey of California; J. D. Whitney, State Geologist. Botany, Vol. II; by Sereno Watson. Cambridge, 1880. Roy. 8vo., xv and 559 pp.

CANADA.

Geological Survey of Canada; Alfred R. C. Selwyn, Director. Report of Progress for 1878–79. Montreal, 1880. 8vo., x, 14, 239, 72, iv, 26, 25 pp., 29 plates, and 5 maps.

FLORIDA.

Omit the pamphlet in Supplement I.

XXXth Congress, 1st Session. Senate, Rep. Com., No. 242. Report of Committee on Draining the Everglades of Florida. Washington, 1848. 8vo., 131 pp.

INDIANA.

State of Indiana. Second Annual Report of the Department of Statistics and Geology, 1880. To the Governor. Indianapolis, 1880. 8vo., 544 pp., 4 maps, and 11 plates. [John Collett.]

IOWA, WISCONSIN, AND ILLINOIS.

Another edition of the report referred to in the Catalogue contains 161 pp.

MARYLAND.

Insert the following list of official publications of the Geology of Maryland in place of that given in the catalogue:

XXIIId Congress, 1st Session. H. of R., Report No. 414; by Hon. Charles Fenton Mercer, on Chesapeake and Ohio Canal, and Baltimore and Ohio Railroad Companies. Washington, 1834. 8vo., 378 pp., and plate.

*Report of Hon. William Cost Johnson. H. of R., Doc. No. 168. Washington, 1836.

Md. House of Delegates. Sess. Dec., 1832. Report of the Select Committee relative to the Expediency of procuring a Map of the State. L. W. Jenkins, Chairman, Annapolis. 1833. 8vo., 10 pp.

Md. Sess. Dec., 1833. Report on the projected Survey of the State of Maryland, pursuant to a Resolution of the General Assembly. Annapolis, 1834. 8vo., 39 pp. and map. J. T. Ducatel and J. H. Alexander.]

[Another edition. Annapolis, 1834. 8vo., 58 pp. and map.]

[Another edition. Annapolis, 1834. 8vo., 43 pp., and folded table.]

Md. House of Delegates, Sess. Dec., 1833. William D. Merrick, Chairman. Report of the Committee on Internal Improvement [sic]. Relative to a Map and Survey of the State of Maryland. Annapolis, 1834. 8vo., 6 pp.

Report on the New Map of Maryland, 1834. n. d. 8vo., 59, 1 pp., 2 maps, and 1 folded table. [J. T. Ducatel and J. H. Alexander.]

[Part of above issued separately. Engineer's Report [for 1834]. 8vo., 12 pp.]

[Part of above issued separately. Report [of the Geologist for 1834]. 8vo., pp. 13–59, 2 maps and folded table.]

[Another edition. Report of the Geologist to the Legislature of Maryland, 1834. n. d. 8vo., 50, 1 pp., 2 maps and folded table.]

Report of the New Map of Maryland, 1834. n. d. 8vo., 15 pp.

Md. Sess. Dec., 1835. Report of the Engineer and Geologist in relation to the New Map, to the Executive of Maryland. Annapolis, 1836. 8vo., 84, 1 pp., 6 maps, and plate. [J. T. Ducatel and J. H. Alexander.]

[Separately printed, as parts of the above: Report on the New Map of Maryland, 1835. 8vo., 34 pp., 6 maps. Also, Report of the Geologist. n. d. 8vo., 35–84 pp., plate.]

[Another edition. 96, 1 pp., and maps, and plate.]

Md. Sess. Dec., 1836. Report on the New Map of Maryland, 1836. n. d. 8vo., 117 pp., and 6 maps. [J. H. Alexander and J. T. Ducatel.]

[Another edition. 8vo., 104 pp., and 5 maps.]

[Part of the above in: Communication from John H. Alexander, Esq., Topographical Engineer, to the Governor of Maryland. Annapolis, 1838. 8vo., 15 pp.]

Md. Sess. Dec., 1837. Document [R.]. Mr. Kerr, Chairman. Report of the Select Committee appointed to inquire into the Expediency of Repealing the Act to provide for completing a New Map, and Geological Survey of this State. n. d. 8vo., 8pp.

[Another edition. 8vo., 4 pp.]

Communication from the Topographical Engineer. [John H. Alexander.] 8vo., 4 pp. n. d. [1838.]

Report of the Treasurer of the Western Shore to the House of Dele-

gates respecting the Expenses incurred in making the Geographical and Geological Survey of the State. n. d. 8vo., 3pp. [1838.]

Annual Report of the Geologist of Maryland, 1837. n. d. 8vo., 30, 1 pp. and 2 maps. [J. T. Ducatel.]

Md. Sess. Dec., 1838. Report of the Treasurer of the Western Shore to the House of Delegates of Maryland. In obedience to their order of the 28th ultimo, stating the Expenses incurred in making the Geographical and Geological Surveys of the State. n. d. 8vo., 2 pp. [1839.]

Document L. Mr. Wharton. Report of the Select Committee appointed by the House of Delegates to Report a Bill to Abolish the Office of State Geologist. n. d. 8vo., 3 pp. [1839.]

Annual Report of the Geologist of Maryland, 1838. n. d. 8vo., 33, 1 pp. and 4 plates. [J. T. Ducatel.]

Md. Sess. Dec., 1839. Annual Report of the Geologist of Maryland, 1839. n. d. 8vo., 45, 1 pp. and 2 maps. [J. T. Ducatel.] [1840.]

Md. Sess. Dec., 1840. Trigonometrical Survey for the New Map of Maryland, 1841. n. d. 8vo., 8 pp. [Dated Feb. 2d, 1841. J. H. Alexander.]

Md. Sess. Dec., 1840. Trigonometrical Survey for the New Map of Maryland, 1841. n. d. 8vo., 4 pp. [Dated Feb. 19th, 1841. J. H. Alexander.]

Md. Sess. Dec., 1840. Annual Report of the Geologist of Maryland, 1840. n. d. 8vo., 43 pp. and 3 plates. [J. T. Ducatel.]

[Another edition. 8vo., 59 pp. and 3 plates.]

[Another edition. 8vo., 46 pp. and 3 plates.]

Md. Sess. Dec., 1841. Report of the Topographical Engineer to the Governor of Maryland. n. d. 8vo., 5 pp. [J. H. Alexander, 1842.]

Md. Sess. Dec., 1843. Report of the Committee on Agriculture relative to the Application of Lime to the different Qualities of Soil and the use of calcareous Matter for agricultural Purposes. In obedience to an order of the House of 27th of January. Annapolis, 1844. 8vo., 15 pp.

Md. Sess. Dec., 1846. Document T. Order of the House. Report of the Committee on Agriculture in Relation to the appointment of an agricultural Chemist. n. d. 8vo., 8 pp.

Md. Sess. Dec., 1849. Report of the Committee on Agriculture in Pursuance of the Order of the Senate of 20th February. n. d. 8vo., 7 pp.

Report of James Higgins, State Agricultural Chemist, to the House of Delegates of Maryland. n. d. [1850.] 8vo., 92 pp.

Md. Sess. Jan., 1852. The Second Report of James Higgins, State Agricultural Chemist, to the House of Delegates of Maryland. Annapolis, 1852. 8vo., 126 pp.

Md. Sess. Jan., 1853. The Third Report of James Higgins, State Agricultural Chemist, to the House of Delegates of Maryland. Baltimore, 1853. 8vo., 160 pp.

Md. Sess. Jan., 1854. The Fourth Annual Report of James Higgins, State Agricultural Chemist, to the House of Delegates of the State of Maryland. Baltimore, 1854. 8vo., 92 pp.

Md. Sess., Jan., 1856. Fifth Agricultural Report of James Higgins, State Chemist, to the House of Delegates of the State of Maryland. Annapolis, 1856. 8vo., 91, 1 pp.

[Another edition, pp. 15–18 omitted. 8vo., 90, 1 pp.]

Md. Sess. Jan., 1858. J. Higgins. State Chemist's Report. n. d. [1858.] 8vo., 96, xxii pp.

[Another edition of above has title; Sixth Agricultural Report of James Higgins, State Chemist to the House of Delegates of the State of Maryland. Order of House and Senate. Annapolis, 1858. 8vo., 96, xxii pp.]

First Report of Philip T. Tyson, State Agricultural Chemist, to the House of Delegates of Maryland, Jan., 1860. Annapolis, 1860. 8vo, xi, 145, 20 pp. and 2 maps.

Report of the State Chemist. n. d. [1860.] 8vo., 4 pp.

Second Report of Philip T. Tyson, State Agricultural Chemist, to the House of Delegates of Maryland, Jan., 1862. Annapolis, 1862. 8vo., 92 pp.

Report of the Select Committee appointed to prepare a Statement in Relation to the Resources of Maryland. Annapolis, 1865. 8vo., 52 pp.

Md. Sess. Jan., 1866. Report of William R. Cole, Esq., Chief Clerk of House of Delegates, in Relation to the Distribution of the Report of the Select Committee on the Resources of Maryland. Annapolis, 1866. 8vo., 16 pp.

Report of Select Committee on the Resources of the State. Annapolis, 1866. 8vo., 2 pp.

Md., Jan. Sess. 1867. A succinct Exposition of the Industrial Resources and Agricultural Advantages of the State of Maryland. By James Higgins, late State Agricultural Chemist. n. d. [1867.] 8vo., 109, iii pp.

MICHIGAN.

* XXVIIIth Congress, 2d Session. Senate Ex. Doc., No. 17. Report of the Secretary of War communicating Information Facilities of Approach to, and Intercourse with, the mineral Reg of Lake Superior. Washington, 1845. 8vo., 9 pp. [G. W. Sanders.]

In place of Report in Supplement I read: XXIXth Congress Sp. Session. Senate Ex. Doc., No. 175. Report of the Secretary of War communicating a Report of John Stockton, Superintendent of the Mineral Lands on Lake Superior. Washington, 184 8vo., 22 pp. and map. [John Stockton, J. B. Campbell, G. W Sanders, and A. B. Gray.]

In Catalogue in place of A. B. Gray, etc., read: XXIXth Congress 1st. Session. H. of R. Doc., No. 211. Mineral Lands of Lake Superior. Letter from the Secretary of War relative to the Mineral Lands on Lake Superior. Washington, 1846. 8vo. 23 pp. and map. [A. B. Gray.]

XXIXth Congress, 1st Session. Senate Ex. Doc., No. 357. Report of the Secretary of the Treasury communicating, in Compliance with a Resolution of the Senate, Information relative to the Character and Condition of the Mineral Regions in the Lake Superior Country in the State of Michigan and Territory of Wisconsin. Washington, 1846. 8vo., 29 pp. [Bela Hubbard.]

XXXth Congress, 1st Session. Senate Ex. Doc., No. 2. Report from the Acting Secretary of the Treasury, communicating the Annual Report of the Commissioner of the General Land Office. Washington, 1847. 8vo., 230 pp. [Contains C. T. Jackson's Report of Progress of the Geological Survey of the Mineral Lands of the United States to Michigan in October 27th, 1847.]

XXXth Congress, 2d Session. Senate Ex. Doc., No. 2. Report from the Secretary of the Treasury communicating the Annual Report of the Commissioner of the General Land Office. Washington, 1848. 8vo., 191 pp. [Contains Reports of C. T. Jackson, J. D. Whitney and J. W. Foster on the Mineral Lands of the United States in Michigan.]

XXXIst Congress, 2d Session. Senate Ex. Doc., No. 2. Report of the Secretary of the Interior, communicating a Report of the Commissioner of the General Land Office, exhibiting the Operations of that Branch of the Public Service during the last Year. Washington, 1851. 8vo. [Contains a Report on Lake Superior Mining Region, by J. W. Foster and J. D. Whitney.]

*XXXIst Congress, — Session. H. of R., Ex. Doc., No. 12. 1848–49. Washington, 1849.. 8vo. [Contains Report of Progress of Survey of Mineral Lands by Charles T. Jackson, pp. 153–163; also additional Report of same, pp. 185–191.]

MINNESOTA.

In first title of Catalogue insert "Senate" before Ex. Doc.; also add "and map."

The Geological and Natural History Survey of Minnesota. The Eighth Annual Report for the Year 1879. St. Paul, 1881. 8vo., 183, iv pp., map and plate. [N. H. Winchell.]

NEW JERSEY.

Geological Survey of New Jersey. Annual Report of the State Geologist for the Year 1880. Trenton, 1880. 8vo., 220 pp., and 2 maps. [Geo. H. Cook.]

NEW YORK.

The Annual Report for 1838 has a 4to. Atlas, containing 10 plates of scenery, 2 plates of sections, 3 maps, and table of minerals. [The last sometimes bound in with report.]

Vol. I of Zoology is sometimes bound so as to contain 4to., 188 pp., and 2 plates. [W. H. Seward.] And xiii, and 146 pp., and 33 plates.

*Vol. IX. Transactions New York State Agricultural Society. Albany, 1850. Contains Survey of Washington County by Dr. Fitch.

*Vol. XXII. Transactions New York State Agricultural Society. Albany, 18—. Contains Survey of Orange County by G. Denniston.

State of New York. No. 53. In Assembly, January 30th, 1855. Report of the Commissioners appointed to superintend the Completion of the Publication of the Natural History of New York. 8vo., 24 pp.

State of New York. No. 211. In Assembly, April 8th, 1856. Report of the Select Committee on the Completion of the Natural History of the State. 8vo., 16 pp.

State of New York. No. 79. In Assembly, March 5th, 1879. Report of the Committee on Public Education relative to the Geological Survey and Natural History of the State. 8vo., 16 pp.

North Carolina and Georgia.

XXIst Congress. Second Session. H. of R. Rept. No. 82. Assay Offices. Gold Districts of North Carolina and Georgia. Washington, 1831. 8vo., 29 pp.

North Carolina.

*The Minerals and Mineral Resources of North Carolina: being Chapter I of the Second Volume of the Geology of North Carolina. Raleigh, 1881. 8vo., 122 pp.

Pennsylvania.

Second Geological Survey of Pennsylvania: Report of Progress in 1877. CCC. The Geology of Lancaster County; by Persifor Frazer, Jr. Harrisburg, 1880. 8vo., x and 350 pp., 10 plates, and atlas of 13 maps and sections.

Second Geological Survey of Pennsylvania: Report of Progress. GG. The Geology of Lycoming and Sullivan Counties. 1, Field Notes by Andrew Sherwood; 2, Coal Basins by Franklin Platt. Harrisburg, 1880. 8vo., ix and 268 pp., and 4 maps.

Second Geological Survey of Pennsylvania: Report of Progress in 1876–79. GGG. The Geology of Potter County, by Andrew Sherwood. Report on the Coal-fields by Franklin Platt. Harrisburg, 1880. 8vo., xvi and 121 pp., 2 maps, and plate of sections.

Second Geological Survey of Pennsylvania: Report of Progress. G4. Part I. The Geology of Clinton County. Part II. A Special Study of the Carboniferous and Devonian Strata along the West Branch of the Susquehanna River, by H. Martyn Chance. Included in this Report are a Description of the Renovo Coal-basin, by C. A. Ashburner; Notes on the Tangascootack Coal-basin, in Centre and Clinton counties, by Franklin Platt. Harrisburg, 1880. 8vo., xiv and 183 pp., and 3 maps.

Second Geological Survey of Pennsylvania, 1879. Report of Progress in Armstrong County; by W. G. Platt. Harrisburg, 1880. 8vo., lxvii and 338 pp., and map.

Second Geological Survey of Pennsylvania, 1875 to 1879. The Geology of the Oil Regions of Warren, Venango, Clarion, and Butler counties, including Surveys of the Garland and Panama Conglomerates in Warren and Crawford, and in Chatauqua Co., N. Y. Description of the Oil-well Rig and Tools, and a Di-

cussion of the Pre-glacial and Post-glacial Drainage of the Lake Erie Country; by John F. Carll. Harrisburg, 1880. 8vo., xxiv and 482 pp., 2 plates, and atlas of 22 maps and plates.

Second Geological Survey of Pennsylvania, 1878–80. Catalogue of the Geological Museum by Charles E. Hall. Part II. 1, Collections of Rock Specimens. 2, Palæontological Specimens. Harrisburg, 1880. 8vo., viii and 272 pp.

Second Geological Survey of Pennsylvania. Report of Progress, P. Description of the Coal Flora of the Carboniferous Formation of Pennsylvania, and throughout the United States. Vol. I. 1, Cellular Cryptogamous Plants (Fungi, Thalassophytes). 2. Vascular Cryptogamous Plants (Calamariæ, Filicaceæ). Vol. II. 1, Lycopodiaceæ; 2, Sigillariæ; 3, Gymnosperms. By Leo Lesquereux. Harrisburg, 1880. 8vo., xv, 354, v, 355–694, lxviii pp., and 3 plates.

Second Geological Survey of Pennsylvania: Report of Progress R. The Geology of McKean County and its Connection with that of Cameron, Elk, and Forest; by Charles A. Ashburner. Harrisburg, 1880. 8vo., xii and 371 pp., 8 plates and table, and atlas of 8 maps and sections.

Second Geological Survey of Pennsylvania: Report of Progress in 1879. VV. The Geology of Clarion County; by H. Martyn Chance. Harrisburg, 1880. 8vo., xv and 232 pp., 4 plates and 3 maps.

Second Geological Survey. Report of the Board of Commissioners. January, 1881. —, 1881. 8vo., 5 pp. and maps.

Second Geological Survey of Pennsylvania: Report of Progress, 1879. QQQQ. The Geology of Erie and Crawford counties; by I. C. White. Discovery of the Pre-glacial Outlet of Lake Erie; by J. W. Spencer. Harrisburg, 1881. 8vo., xxi and 406 pp., and 4 maps.

Second Geological Survey of Pennsylvania: Report of Progress, T. The Geology of Blair County; by Franklin Platt. Harrisburg, 1881. 8vo., 311 pp., and atlas of 17 sheets.

Rocky Mountain Region.

In Supplement I strike out "Erase XXXIVth Congress. H. of R. Doc., No. 129. Washington, 1855. 43 pp."

In same, Cross's Report of Expedition from Fort Leavenworth to Fort Vancouver, is said to contain 36 plates. It is doubtful if they were ever printed.

In same, strike out, Thaddeus A. Culbertson's Journal, as it is not an official government report.

Vol. III. of Powell's Contributions to North American Ethnology contains 43 plates.

Abert's Report of New Mexico, 1848, 132 pp. Was also published as XXXth Congress, 1st Session. Senate Ex. Doc., No. 23.

XXXIst Congress, 2d Session. Senate Ex. Doc., No. 19. Report of the Secretary of War communicating, in answer to a Resolution of the Senate, the Report of Lieut. Whipple's Expedition from San Diego to the Colorado. Washington, 1851. 8vo., 28 pp.

XXXIVth Congress, 1st and 2d Sessions. Senate Ex. Doc., No. 1, Pt. 2. . Contains pp. 90–98, Report of Capt. A. A. Humphreys, U. S. A., upon the Progress of the Pacific Railroad Explorations and Surveys. Washington, 1855. 8vo.

*XXXVth Congress, 1st Session. H. of R. Ex. Doc., No. 124. Wagon Road from Fort Defiance to the Colorado River. Letter from the Secretary of War transmitting the Report of the Superintendent of the Wagon-road from Fort Defiance to the Colorado River. Washington, 1858. 8vo., 87 pp., and map. [Ed. F. Beale.]

XXXVIth Congress, 1st Session. Senate Ex. Doc., No. 2, contains pp. 540–548. Report of Capt. A. A. Humphreys, in charge of office of Explorations and Surveys to Nov., 1859. Washington, 1859. 8vo. [Contains a Report of Capt. John Pope's on Artesian Wells.]

XLIId Congress, 2d Session. Senate Ex. Doc., No. 66. Letter from the Secretary of War accompanying an Engineer Report of a Reconnoissance of the Yellowstone River in 1871. Washington, 1872. 8vo., 43 pp. and map. [Captains Barlow and Heap.]

The Annual Report of the Chief of Engineers to the Secretary of War for the Year 1872. Washington, 1872. 8vo. Contains pp. 1108–1118, Report of Capt. W. A. Jones of a Survey and Exploration in the Uintah Mountains, Utah.

Also, pp. 1126–1172, Report of the Sutro Tunnel Commission.

Preliminary Report of the Fieldwork of the United States Geological and Geographical Survey of the Territories, under the Direction of Prof. F. V. Hayden for the Season of 1877. Washington, 1877. 8vo., 35 pp.

Report on the Geographical and Geological Survey of the Rocky Mountain Region by J. W. Powell. Washington, 1877. 8vo., 17 pp.

Report of the Chief of Engineers to the Secretary of War for the Year 1868, contains Gen. Warren's Report on the Survey of the Mississippi and Missouri Rivers.

Report of the Committee appointed under the Provisions of the Act of Congress of March 3d, 1877, regarding the Hot Springs Reservation in the State of Arkansas. Washington, 1877. 8vo., 12 pp.

Annual Report upon the Geographical Surveys, West of the 100th Meridian; by Capt. Geo. M. Wheeler, U. S. A.; being Appendix OO of the Annual Report of the Chief of Engineers for 1879. Washington, 1879. 8vo., 36 pp. and 5 maps.

Report of the Chief of Engineers to the Secretary of War for the Year 1879. Contains pp. 2331–2343, Appendix RR, Chemical Report on the Pagosa Springs of Colorado by Charles Smart, Asst. Surgeon, U. S. A.

Department of the Interior. Report of the Fieldwork after U. S. Geological and Geographical Survey of the Territories for the Season of 1878. Washington, 1878. 8vo., 29 pp. [F. V. Hayden.]

Eleventh Annual Report of the United States Geological and Geographical Survey of the Territories, embracing Idaho and Wyoming; being a Report of Progress of the Explorations for the year 1877; by F. V. Hayden, U. S. Geologist. Washington, 1879. 8vo., xxviii and 720 pp., and — plates.

Department of the Interior. Report of the U. S. Geological Survey of the Territories. F. V. Hayden, U. S. Geologist-in-charge. Vol. XII. Fresh-water Rhizopods of North America; by Joseph Leidy. Washington, 1879. 4to., xi and 324 pp., and 48 plates.

Department of the Interior. U. S. Geographical and Geological Survey of the Rocky Mountain Region. J. W. Powell, in-charge. Report on the Geology of the High Plateau of Utah, by Capt. C. E. Dutton, U. S. A. Washington, 1880. 4to., xxxii and 307 pp., and atlas of — plates.

United States Geological Exploration of the Fortieth Parallel. Clarence King, Geologist-in-charge. Vol. VI. Odontornithes: a Monograph on the Extinct toothed Birds of North America; by Othniel Charles Marsh. Washington, 1880. 4to., xv and 201 pp., and 34 plates.

TEXAS.

XXXIst Congress, 1st Session. Senate Ex. Doc., No. 32. Report of the Secretary of War communicating a Map showing the Operations of the Army of the United States in Texas and the adjacent Mexican States on the Rio Grande; accompanied by astro-

nomical Observations and Descriptions, and military Memoirs of the Country. Washington, 1850. 8vo., 67 pp., 8 plates, and 2 maps. [Maj. Geo. H. Hughes, U.S.A.]

United States Geological Survey.

First Annual Report of the United States Geological Survey to the Hon. Carl Schurz, Secretary of the Interior; by Clarence King, Director. Washington, 1880. Large 8vo., 79 pp., and map.

XLVIth Congress, 2d Session. Senate Mis. Doc., No. 48. Letter from the Director of the United States Geological Survey, transmitting, in response to a Letter of the Hon. Henry G. Davis, Answers to certain Inquiries propounded in the said Letter. Washington, 1880. 8vo., 3 pp.

Virginia.

Report of the Progress of the Geological Survey of the State of Virginia for the Year 1841; by William B. Rogers. Richmond, 1842. 8vo., 12 pp.

*A Handbook of Virginia; by the Commissioner of Agriculture. Richmond, 1879. [Thomas Pollard.]

West Virginia.

Catalogue of the West Virginia State Exhibit, at the International Exhibition at Philadelphia, in 1876; by M. F. Maury. Philadelphia, 1876. 8vo., 38 pp.

*The West Virginia Handbook and Immigrant's Guide. A Sketch of the State of West Virginia. Geographical Position, Historical Outline, State Constitution, Surface and Soil, Agriculture, Stock-farming, Wool-growing, Fruit and Wine-growing, Timber, Coal, Iron, Petroleum, Salt, and other Minerals, Education, Religious Worship, Lands and Farms, Titles and Prices, with a brief Notice of each County, and an official State Directory and Map; by J. H. Diss DeBar, State Commissioner of Immigration. Parkersburg, 1870. 12mo., 193 pp., and map.

Wisconsin and Iowa.

XXXth Congress, 1st Session. Senate Ex. Doc., No. 2. Report from the Acting Secretary of the Treasury, communicating the Annual Report of the Commissioner of the General Land Office. Washington, 1847. 8vo., 230 pp. Contains D. D. Owen's Preliminary Report, containing Outlines of the Progress of the Geological Survey of Wisconsin and Iowa, up to October 11th, 1847.

THE FORMATION OF GOLD NUGGETS AND PLACER DEPOSITS.

BY T. EGLESTON, PH.D., SCHOOL OF MINES, NEW YORK CITY.

THE origin of gold both in placer deposits and in veins, and especially the origin of nuggets, has been the subject of repeated discussions and investigations, which have been recently brought to my attention by several extremely interesting specimens sent to me for examination, and more especially by the one exhibited at the meeting of the Institute in February, 1880.* In the year 1874 I made some examinations of the hydraulic mines of California, and was very much struck with the distribution of the gold throughout these deep placers, which were almost invariably poor on the surface, while gradually growing richer towards the bed-rock. The constant presence of fossil wood, and the large quantity of organic matter contained even low down in these beds, was also remarkable. Not being satisfied with the various theories advanced to account for the formation of these deposits, I began an investigation early in the year 1879 on the conditions of solubility of gold and the causes of the loss in working gold ore in a large way. The researches which I have undertaken show that gold must be considered a soluble rather than an insoluble metal, and that the conditions of solution are such as will be found anywhere where gold is likely to occur, and the solution may take place even under the ordinary circumstances of surface drainage, and may be going on freely even where the presence of gold has never been suspected, and that there are causes enough in nature to produce the solution of the gold in sufficient quantities to account for all the phenomena of both the vein and placer formations.

The general theory with regard to the formation of these placer deposits and nuggets has been that they were the result of the destruction of pre-existing vein-matter, which does not accord with the facts as shown in the deep placer deposits. The gold in such case would be distributed in layers of unequal richness throughout

* Transactions of the American Institute of Mining Engineers, vol. 8, p. 451.

the bed, the richness depending on the amount of deposition taking place at any one time, and would not occur in increasing richness from the top to the bottom. Further, every particle of gold of whatever size would have a rounded form, resulting from its abrasion against the harder rocks, which is not the case, the small as well as the large grains being of very irregular shape. It must also be borne in mind that most of the veins from which the gold is supposed to have come had a gangue of quartz. The gold is much softer than the rock; the quantity of precious metal contained in the vein would also be very much less than the rock, so that in the destruction of the formations there would be a very small amount of gold being abraded and ground in a very large quantity of rock. It is therefore likely that the coarse particles of gold, which is so much softer, would be comminuted at least as fine as the rock, and the smaller ones much finer than the rock, so that the difference in density would hardly tend to make a concentration by any subsequent action of wind or water, since the small particles of gold would tend to float away and thus prevent the concentration. Where the large particles are not in sufficient quantity to make an extended natural concentration possible, and where the deposition of the sediment of the rivers is taking place, the result would be a very small quantity of almost impalpably fine gold, distributed uniformly in a very large amount of comminuted rock, or a production of clays resembling that used to make brick around Philadelphia, which contains very small amounts of gold uniformly distributed through it. The structure, too, of each one of these particles would be the same as that of the rock with which it was abraded, and would be uniform. It is, however, well known that the grains of gold found in the placers are not uniform; some of them are flattened with rounded edges, others rounded, and most are mammillary, all of which forms are not probable, and hardly possible, under the conditions suggested. A nugget rounded like a water-worn pebble is a great exception in any of the placer deposits.

While the theory of vein destruction might in some cases account for the presence of gold in small quantities throughout the sands in grains large enough to admit of concentration, it could never account for the presence of large nuggets, which if they had been transported any distance by water would have lost their mammillary form. Admitting the greater size and force of the ancient rivers, it is impossible to conceive that such large and irregularly shaped nuggets as those from Australia, Siberia, and from this country could ever

have been so transported by water as to be entirely relieved of all their gangue, without having themselves assumed much more regular surfaces and a more uniformly cobble-stone shape. On the other hand, slow accumulations from solutions of varying strength and a deposition of unequal rapidity continued for a great length of time, accounts perfectly both for the form and for all the attendant phenomena. It is a fact, moreover, that very large masses such as these nuggets have never been found in veins, and are confined exclusively to placer deposits. The detrital theory accounts still less for the fact that in many of the deposits, especially where the bed-rock is soft and porous, the gold often enters it to the depth of nearly a foot, and it is frequently the richest part of the deposit.

In 1867 Mr. Wilkinson, of Australia, made a series of researches with reference to the effect of organic material on the deposition of gold. Sonstadt* also made a series of researches on the presence of gold in sea-water, and found it to be present in the ratio of about one grain to the ton of water, or about $1 for every 25 tons of water.

Up to this time gold had always been considered as a very insoluble substance, because it was insoluble or very nearly so in most mineral acids. Ingenious metallurgical processes based on this insolubility have been invented, and are still in constant use; but it does not follow that because gold is not affected by the ordinary acids it is therefore not soluble in other substances much more likely to be found in nature. The action of organic acids and of the alkalies were left out of view, and also the fact that the solution of infinitesimal quantities may acquire great significance in a geological sense.

Bischoff found that sulphide of gold is slightly soluble in meteoric waters, and much more soluble in a saturated solution of sulphuretted hydrogen in water. It has also been ascertained that chloride of gold in minute quantity in an alcoholic solution may remain in solution in the presence of proto-salts of iron, and that metallic gold is slightly soluble in solutions of the per-salts of iron. But the theories founded on these discoveries supposed that gold was much less soluble than it really is, and that the solution required peculiar agencies and a set of circumstances not likely to occur everywhere. Its diffusion in sea-water was accounted for by the presence of chlorine, iodine, bromine, and of alkalies, and these conditions were not thought to be of general application in the explanation of the phenomena exhibited in mineral veins.

* Chem. News, vol. xxvi, p. 159; Am. Chemist, vol. iii, p. 206.

Mr. Selwyn, the government geologist of Victoria, proposed a theory of solution to account for the formation of nuggets and placer deposits, suggesting that the gold was dissolved by the waters which filtered through the soil, was carried in solution until it met some nucleus around which it could deposit, and was then precipitated, and that nuggets and placer deposits were formed in this way. He does not, however, state what he supposed the cause of the solution to be, and suggests that the gold is undoubtedly deposited on particles of gold previously existing in the sands.

These researches and theories, however, did not attract very much attention, and the old theory of the destruction of pre-existing veins was still adhered to. It is to be observed, however, that when gold does come from the destruction of veins the surfaces are rounded and worn smooth, as is shown in the large boulder of quartz containing gold detached from a vein in Venezuela, which is now in the collection of the School of Mines. This is in entire contradiction to the mammillary structure of the nuggets. If they had been transported far by water they would have been rounded and water-worn to much more regular surfaces. These worn surfaces would of course have been confined entirely to the outside of the nuggets, any cavities existing in the interior of the piece would have been in the condition in which they left the vein, and the edges of any crystals found there would have been sharp; while in the nuggets the mammillary form exists even in the cavities of the interior, and even where crystals or the commencement of crystallization is observed, the edges of the crystal are very often blunted or rounded, showing both deposition and solution on these edges.

It is also to be noticed that the analyses of nearly all the samples of gold taken from veins show it to be much less pure than the nuggets found in the placer mines of the same district. If the gold of the placers had come from eroded rocks it would be of the same composition as that of the veins of the district in which it was found. It is well known that most of the gold nuggets are pure, while the gold of the veins is of a much lower grade, containing considerable quantities of silver and other foreign metals. Thus the Ballarat nuggets are 992.5 fine, the Australian nuggets vary from 960 to 966; those from veins in California from 875 to 885; in Transylvania 600 with 399 of silver, and in Nevada there are some of 554 of gold and 429 of silver, and others only 333 of gold with 666 of silver.

It must be remembered also that the violence of the old placer

currents was very much greater than that of the ordinary streams of these days. The rivers were not only larger and deeper, but more rapid, and the results of their action would have been an almost complete comminution of the gold by its rubbing against the harder rocks. If this were the whole of the process and no further action had taken place, the gold would be found in the sands in this comminuted condition exclusively, and few if any of the particles would have escaped the battering and pounding process incident to long exposure to rolling rocks; and the deposits resulting from it would be found on the bed of the stream.

Gold is, however, also found as nuggets, and in small particles in rocks which have never been disturbed from their original positions, but which have been decomposed to a considerable depth; and it then has the same rounded form, occupying positions which make it evident that it must have been formed *in situ*, and never have undergone any abrasive action. The nugget found in 1828, in Cabarrus County, N. C., which weighed 37 pounds, and also the one found in the Valley of Taschku Targanka, near Miask, in Siberia, which weighed 96 pounds, were both found under such circumstances in a decomposed dioritic rock. In some few cases it has been definitely ascertained that the gold has been dissolved and precipitated in the decomposed rocks, for it has penetrated only just so far as the decomposition has allowed it, the yield in gold ceasing entirely at the point where the rock allowed no further filtration; while in other rocks of a more porous nature in the same district the gold has penetrated to a depth not yet ascertained. Such a condition of things is not uncommon in the gold belts of the Southern States.

Admitting that heavier masses of gold did exist in the veins disintegrated by the ancient rivers, gravity alone cannot account for the bottom deposits (which are often 300 feet from the surface) being the richest. It would have required greater agitation of the earth than we have any evidence for believing ever took place to sift the coarse particles even through 50 feet depth of earth, and there is no indication that these deposits after they were once made were ever disturbed. It is undoubtedly true that in shallow placers, where the bed-rock comes near the surface, the surface-soil is rich; but it is the invariable rule that in the deep placers the richest deposits are near the bed-rock, and at a great distance from the surface.

There is a tradition, which is prevalent in all the gold mines of the South, and in those of some other districts, to the effect that gold *grows*, so that every few years the tails of the old mines are re-

worked, generally with a profit; the quantity separated each time, according to the local tradition, being in proportion to the length of time the material has remained undisturbed. As there is no opportunity for the gold in these sands to accumulate by gravity, the people of the region believe that gold grows like a plant.

It would not, however, be rational to deny a theory so easily explained as the formation of placers by the destruction of vein-matter without having some other to replace it. If the theory of the destruction of pre-existing veins is not tenable, we are bound to examine carefully whether there are causes in nature sufficient to account for solution, and what are the agencies that render the gold soluble. A series of experiments have been made on this subject lasting over many months, both synthetical and analytical, which seem to be of considerable importance in the study of the origin both of placer and vein phenomena. In this investigation most of the known salts of gold were prepared; but as the chloride is most easily made, this was made the basis of almost all the solutions. While making the chloride of gold for the solutions some sponge-gold was placed in a tube and heated in a current of chlorine-gas until the chloride of gold formed was entirely sublimed. It deposited at the upper part of the tube directly over the gold, and as the tube cooled, on the gold also, in fine transparent crystals half an inch long. This tube, when cool, was closed while full of chlorine, by replacing the glass tubes by glass rods, and the joints made tight with paraffine. In five months the crystals were melted into a mass, and in a year the whole of the chloride had been transformed into metallic gold with occasional nodules of chloride through it; but the whole of it could be readily amalgamated.

In order to ascertain the effect of different organic substances on salts of gold in solution, five portions of fifty cubic centimeters each of a solution containing .50 gram of chloride of gold were treated in different ways. The first was covered with a cubic centimeter of petroleum. In the second a quarter of a gram of cork was placed; in the third a quarter of a gram of peat; in the fourth half a gram of leather; in the fifth half a gram of leaves. These solutions were put in a dark place, and were left for three months before examination. When the solution containing the petroleum was brought to the light the liquid had lost its color, and there were suspended in it a number of very fine and long crystals of gold, distributed nearly uniformly from the top to the bottom, and floating almost perpendicularly in the water. They had the appearance

of the hexagonal crystals described by Professor Chester.* As soon as the liquid was agitated they fell to the bottom. The solutions containing the cork, leather, and leaves had also been rendered colorless, but the gold had entered into these substances, replacing the organic matter, so that they were pseudomorphed into gold. The solution in which the peat was placed was also colorless, but the gold was precipitated in the form of very small mammillary masses, recalling perfectly the form of nuggets.

To ascertain the degree of solubility of gold a quantity of pure spongy gold was prepared, and placed in a variety of solutions; some of these were left exposed to the air; others were sealed at the ordinary temperature and pressure of the air for periods of from six to eight months; others were exposed to heat and pressure under varying conditions in an air-bath, arranged in such a way that the temperature could be kept constant for a number of hours at a time. Many of these last tubes burst after the liquid had acquired a tint. Of some of these the contents were entirely lost, of others a sufficient quantity of the liquid was left to test for gold.

Solutions of salt, sulphate of ammonia, chloride of ammonium, chloride and bromide of potassium in sealed tubes, after eight months gave no reaction. Heated for five hours at temperatures varying from 150° to 200° C., none of them, except the bromide of potassium, gave any reaction, and that reacted very strongly. In the sealed tubes the solution of salt, in which a few drops of nitric acid had been placed, reacted for gold; the iodide of potassium gave no immediate reaction, but when evaporated to dryness left a purple residue, soluble in bromine, which reacted for gold. Heated to a temperature of from 100° to 170° C., the iodide of potassium tube gave a reaction for gold not much stronger than the solution before heating.

A solution of commercial nitrate of ammonia, which contained some chloride of ammonium as an impurity, kept in an open tube at the ordinary temperature and pressure for four and a half months, colored the solution bright yellow, and reacted strongly for gold. Two solutions were made each containing five grams of nitrate of ammonia and half a gram of chloride of ammonium in 200 cubic centimeters of distilled water. One of the solutions was left in an open room and the other put in a dark place, and left for eleven days. At the end of that time both reacted strongly and with equal intensity for gold.

* American Journal of Science, 3d series, vol. xvi, p. 82.

Pure sponge-gold was then placed in the following solutions, contained in sealed tubes at the ordinary temperature and pressure for three months. Sulphide of ammonium produced no change and no reaction. With sulphide of potassium a black precipitate was formed, and a strong reaction for gold was given by the liquid. Sulphide of sodium gave a black precipitate and a strong reaction for gold. Cyanide of potassium gave a yellow solution, a brown precipitate and smell of ammonia, and a strong reaction for gold. Chloride of magnesium, after nearly three months, gave a gelatinous precipitate, but no gold. Sulphate of soda, after the same length of time, produced no change and no reaction. The sulphate of copper produced no change after two and a half months.

Spongy gold was then put into solutions of the following substances, and heated for six and a half hours between 145° and 180° C. Sulphide of ammonium showed no apparent change, but reacted strongly for gold. The solution of sulphide of potassium attacked the glass strongly; it looked greenish, and the liquid reacted for gold; a black precipitate was formed, which was dissolved in bromine, and reacted for gold. The solution of sulphide of sodium acted slightly on the glass, and acquired a greenish tint; a pink film was found on the glass, and a slight precipitate was formed. This film reacted slightly, and the solution very strongly for gold; there was not enough of the precipitate to examine. The solution of chloride of magnesium attacked the glass strongly, from which scales fell, but no gold was dissolved. The solution of sulphate of soda gave a cloudy, flocculent precipitate, but no reaction for gold. Commercial sulphuric acid and solutions of sulphate of potash, iron, and manganese gave white scales, but no reaction for gold. Solutions of sulphate and nitrate of soda gave no change and no reaction. The solution of permanganate of potash produced no reaction. In the solution of cyanide of potassium the brown precipitate which was formed in the previous experiment dissolved, reducing the gold in the solution so that no gold was found dissolved.

A mixture of nitrate of silver and sulphuric acid produced no change after two months. A mixture of the sulphates of potash, iron, manganese, and commercial sulphuric acid produced no change after two months. The permanganate of potash and sulphuric acid gave a black precipitate and colored the liquid slightly pink, but gave no gold.

In order to test the effect of organic matter in solution, half a gram of chloride of gold was placed in two liters of Croton water in two large

bottles. One of these was left exposed to the sunlight, and from this all the gold was precipitated in less than a week; the other was placed in a dark room and left there; at the end of eight months a small amount of gold was precipitated. When solid organic matter was placed in the bottle the precipitation was quite rapid, and when the bottle was then brought into the sunlight all the gold was precipitated in about forty-eight hours.

To ascertain the effect of different soils on weak gold solutions half a gram of chloride of gold was dissolved in ten liters of filtered Croton water, and made to pass continuously over the three mixtures given below arranged in glass funnels. The apparatus was so arranged that the liquid would flow drop by drop on the filters.

No. 1 contained 30 grams of quartz sand, No. 2, 20 grams of sand and 10 of soil, No. 3, 30 grams of magnetic iron sand and ten of quartz sand.

The filters were left exposed in a room where there was considerable dust arising, and where there was also the smoke from passing trains. In two days most of the gold had been precipitated in the filters, and the water had a greenish look. Half a gram of chloride of gold was then dissolved in ten liters of distilled water, and filtered in the same way over thirty grams of quartz sand, a mixture of twenty of sand and ten of soil, and a mixture of ten of sand and thirty of magnetic sand. These filters were carefully covered to prevent any dust settling on them, so that they were protected from all organic matter except such as was contained in them. At the end of two months the clean sand and the mixture of magnetic and clean sand had reduced a small quantity of gold (a little more in the latter than the former) in concretionary shapes, which, owing to the rapidity of the action, were not coherent, but could be crushed with the pressure of the finger. In the mixture with the soil the whole had been reduced, and was distributed through the sand as an impalpable powder, no indication of any concretionary form being observed.

The attempt was then made to dissolve gold in a manner similar to that which was supposed to take place in nature. For this purpose filters were prepared of thirty grams each of clean quartz sand; in one of these 1.161 grams of sponge-gold was placed and carefully mixed with the sand; in each of the other two half a gram of very fine gold was mixed. Over the sponge-gold ten liters of distilled water, containing thirty grams of common salt and five grams of nitrate of soda, was made to filter constantly for two months, but no

observable change took place. For the second solution six liters of Croton water were taken, in which nine grams of nitrate of ammonia and one gram of chloride of ammonium were dissolved. This was made to filter constantly for one month, but no gold was dissolved. For the last experiment one gram of nitrate of ammonia and nine grams of chloride of ammonium were used, but no gold was dissolved.

It was the intention to continue these filtrations for six months at a time, and with all the conditions of natural waters, but the difficulty of making the experiments continuous decided the abandonment of them after a number of the other results had been obtained. The failure to dissolve gold in this short time does not prove that there is no action, as the other experiments show. An amount equal to a little less than that in sea-water might easily escape detection. In these experiments there is lacking the certainty that all the conditions necessary to success are fulfilled. It was found in one of the experiments, made in the early stages of the investigation, that the fine dust circulating in the room was sufficient to precipitate the gold from a dilute solution. All these researches had to be made in a room to which many persons had access, and it is quite possible that the organic matter precipitated the gold in these last experiments as fast as it was dissolved; for in the experiments for the production of the placers the organic matter did deposit the gold in the sand. It is greatly to be regretted that these experiments could not have been made in the complete absence of dust.

In order to test the effect of organic life in such solutions, a plant was watered with a very weak solution of gold, but as is often the case in such experiments, the plant died of too much watering. In the anxiety to produce the kind of absorption by plants described by Durocher and Malaguti, the experiment was made a failure by too much enterprise. The examination of the ashes of the plant showed a small amount of gold, but most of the gold precipitated was in the soil around the plant, being thrown down there by the organic material in the earth. This experiment indicates the origin of the thin plates of gold which are sometimes found in the grass roots of certain placer countries.*

It will be observed that in almost all the cases where gold was dissolved, chlorine and some nitrogenous substances were found together in the presence of alkaline waters. These same conditions

* Transactions, American Institute of Mining Engineers, vol. vi, p. 33.

are favorable also to the separation and solution of silica. It has been proven by these experiments that the alkaline sulphides act on gold as well as the substances enumerated above, and it is quite easy to imagine the conditions under which the gold, already in solution in excessively small quantities, coming in contact either with solid or liquid organic matter, may precipitate all the metal.

In Grass Valley, California, I have known of gold being thrown down in the filter of a Plattner's vat by the organic matter contained in the very impure water used there for the solution of the gold rendered soluble by the action of the chlorine. The filter was full of metallic gold, and there was no means of ascertaining how much of it had been lost. Several ounces of a brown deposit were taken from it which was nearly pure gold. This cause of deposition, and of loss in large operations, has, I believe, been entirely overlooked. It is quite easy to explain the presence of gold in alluvial sands by the action of sunlight alone on the waters containing the gold in solution, and to account for the gold on the bed-rock, by the solutions coming in contact with organic or mineral matter, such as the lignites, fossil woods, or the pyrites, which is everywhere found in deep placer deposits. The waters not being able to pass the bed-rock, remain there in contact with the organic matter until all the gold is precipitated. The same would be true of the decomposing rocks, or of slaty strata coming up to the bottom of the deposit at an angle. The deposition would be rendered much more rapid by any electrical currents that might pass through the strata.

In all of these phenomena, time, which in the operations of nature is unlimited, is one of the chief factors. In any laboratory experiment the limit of time must of necessity be short, but there is no such limit in nature. That this solution goes on on a large scale there is every reason to suppose. That it may be connected with vein phenomena the California nugget shows, since in this case both the formation of the quartz and of the nugget are evidently posterior to that of the blue gravel.

It will be seen from these reactions that many of the conditions favorable to the solution of gold are also favorable for the solution of silica, and that, as Professor Kerr shows,* the rocks may be actually decomposed and the gold deposited, forming in this way shallow deposits called veins, in which the gold disappears entirely beyond a few feet.

* Transactions, American Institute of Mining Engineers, vol. 8, p. 462.

Nothing is more likely than that the infiltration of water through rocks undergoing decomposition, of which there are enormous quantities in the gold region, should take up the alkalies, and, slowly passing over the gold, should dissolve it. The composition of these alkaline salts would depend on the nature of the rock through which the waters passed, but it is more than likely that they would be mixtures of many of the compounds likely to attack the gold and carry it off in solution, and not alkaline carbonates and sulphides alone, although these would be likely not only to be present, but to be powerful agents in carrying on the work of solution. In some cases the decay of the rocks is so rapid that the phenomena may, as it were, be caught in the act. The agencies producing the decomposition of the rock, penetrating it beyond the limits of local drainage, and carrying off the soluble parts, leave the débris in a condition easily penetrated by the infiltrating solutions, and ready to receive any deposit which these solutions may for any cause leave behind them. A source of these deposits in the deep placers of California is the trap which sometimes covers the old river deposits to a depth of 150 feet. In the deep placers these waters would be capable of holding the gold in solution until they met some decomposing element, such as particles of metallic compounds, native metals or organic matter, which is always present in large quantities in the deep placers. If a nucleus of metal were present the gold would be precipitated on it, and if none were present then the gold would come down as a powder, each grain of which, however small, would serve as a nucleus for future aggregations.

Admitting the solutions to be even more dilute than the sea-water near the coast of England, yet unlimited time and quantity would evidently produce these effects, redistributing the gold. Iodine, which is a solvent of gold, is found in many of the plants of the gold region, and in considerable quantities in sea-water. Sonstadt* supposes that gold is kept in solution in the water of the sea by the slow rate at which iodate of calcium is decomposed in the sea-water of the temperate zones, but suggests that where the decomposition of the iodate, whose presence is necessary to keep the small amount of gold in solution, is very rapid as in hot countries, the liberation of the nascent iodine, and consequent rapid solution of the gold, and subsequent precipitation by organic matter is quite sufficient to account for the great richness of the gold deposits of tropical countries.

* Chem. News, vol. xxvi, p. 161. Am. Chemist, vol. iii, p. 208.

It seems, by the experiments already cited, to be clearly proved that gold is not only not insoluble, but that in nature it is constantly being dissolved out of the rocks and placers, the waters of filtration dissolving out of the rocks in their passage through them all the materials necessary for the solution of the gold, and carrying it in very dilute solutions until it meets some substance that precipitates it. It seems to be proved that when the action is slow and localized, we have the phenomena of placers with large or small nuggets and irregularly shaped pieces, and when the action is rapid we find the gold in small particles distributed through the sands. We have reason to suppose that these phenomena are now taking place in such a way as to concentrate the gold by infiltration and precipitation in the tailings of mines which cannot be concentrated by mechanical means. Some of these phenomena can be accounted for by the simple action of sunlight, but others, mostly those of the deep placer deposits, have their cause in the large amount of organic material contained in them. The use of a charcoal filter to precipitate the gold from relatively concentrated solutions in one of the recently invented metallurgical processes, is a very suggestive idea of the means nature may have used on an immense scale on very attenuated solutions.

The same conditions which cause the solution of gold in certain cases cause also the solution of silica. This explains the phenomenon of mammillary and apparently water-worn nuggets (like that from Placer County) encased in quartz, while both the gold and the quartz have been formed posterior to the blue gravel. It also explains the presence of "putty stones," as the soft pieces of decomposed rock constantly found in placer deposits are called. Many of the causes which produce the precipitation of the gold would also produce the reduction of soluble sulphates to insoluble sulphides, the gold being retained in the mass. This would account for the almost constant presence of gold in pyrites, or the occurrence of some of the copper ores of Texas in the form of trees, the ore containing both gold and silver, and also for the constant presence of gold in the iron ores of Brazil, the so-called Jacotinga, and also for the presence of trees transformed into iron ore carrying gold in some of our Western States. In many of the deep placers of California the heavy cap of basalt is quite sufficient to account for many of the phenomena which occur not only beneath but around it.

The fact that gold has not as yet been found in potable waters may be simply due to the extreme difficulty attendant on its detec-

tion in minute quantity. It is more than likely that many of the geological phenomena on a large scale were produced by very dilute solutions or very slight forces acting for a very long time. How far the electrical currents of the earth may have been a factor in these phenomena it is impossible to surmise. It is, however, more than probable that they were the result, not of one alone, but of all the causes mentioned, and perhaps many others which have as yet escaped our attention. No single agent is so powerful a solvent of gold as chlorine. Very few drainage-waters are free from some compound of it, and no soil is without the nitrogenous materials necessary to set the chlorine free, and therefore capable of attacking the gold and rendering it soluble. The experiments show that a trace of it is quite sufficient to dissolve enough gold to color a solution so that the eye can detect it after a few week's exposure.

In the nugget of Placer County it would have been impossible for either the gold or the silica to have got into its position except by solution. The iron of the blue gravel in this case seems to have been the first cause of precipitation, and subsequently the gold itself was an active agent in increasing its own weight. The general absence of crystals and of their rounded edges, where they are found, can be easily accounted for by the fact of the rapid action possible in the placers. The readiness of filtration through the easily permeated gravel causes the gold to precipitate so rapidly that there is no time for any but a mammillary deposit; while in vein deposits the extreme slowness of the deposition allows the gold to assume a crystalline shape. When we consider that two-thirds of all the gold produced in the world comes from alluvial deposits, it seems difficult to account for its presence in the sands in any other way than by solution.

THE CAUSE OF RUSTINESS AND OF SOME OF THE LOSSES IN WORKING GOLD.

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THERE has always been a theory among those working placer mines that gold is both found "rusty," and becomes so under treatment, by which they mean, not that gold becomes coated with oxide of gold, but that it is either coated superficially or alloyed with some substance which prevents the contact with mercury, and thus precludes the possibility of amalgamation. To such conditions of the

gold are ascribed the losses in working most placer deposits. Rusty gold is often talked about, but is not often shown, and when produced oftener amalgamates than not. It is frequently covered with a brownish coating, and has a much redder color than ordinary gold. The coating is very irregularly distributed over the surface, every spot where the least abrasion has occurred showing the true gold-yellow. All such spots form contact surfaces, and cause the whole piece to amalgamate readily. When the gold is wholly coated it resists the action of the mercury for a considerable time and perhaps altogether. This coating on gold is due to the superficial action of some substance, which is soluble, and is often precipitated at the same time and by the same causes as the gold, for fine particles of gold are sometimes visible with the microscope in the detached coating. It has never to my knowledge been carefully analyzed. Those who describe it say that it often cracks off from pieces of gold leaving them bright. Nuggets of some size are said to have been found in South America, in alluvial soil, coated with a silicate of iron containing considerable gold. Very often the film is entirely composed of silica, which is deposited on and beside the gold. This silica is sometimes opaque, and again quite transparent, so that the gold can be seen disseminated through it with the microscope, just as cinnabar crystals are seen in the red chalcedony of the district around Knoxville, Cal. When the silica surrounds the gold entirely it prevents the gold from being attacked by the mercury, just as the fine particles of gold from the veins are carried off in the rock when it has not been rendered sufficiently fine in the crushing.

While there are many artificial causes which produce the rustiness of gold, this covering of the surface with particles of some foreign substance is probably the only one which occurs in nature. In the separation of gold from its ore there are a number of causes which render it rusty or prevent its amalgamation in the mill. Some of these causes I have recently had occasion to investigate, and are, I believe, now announced for the first time; others have been more or less known for a number of years.

It has been asserted that the presence of certain substances alloyed with the gold would prevent its amalgamation. This I have generally found not to be the case. I have made a number of these alloys and have found them to amalgamate without difficulty, but chemical combinations frequently do resist the action of the mercury altogether, or when they yield, it is attended with the formation of a chemical compound with the mercury, and the consequent loss of the latter.

In order to ascertain the causes which prevent the amalgamation of gold I undertook to reproduce artificially the conditions which were supposed to prevent it. These I found to be mechanical and chemical. I found that if a piece of soft gold which could be easily bent, and amalgamated readily, was hammered on a perfectly bright anvil, with a bright hammer, giving several rapid blows, until the gold had become hard, and had acquired a certain amount of elasticity, it would remain in juxtaposition with mercury for a very long time without being affected by it. This hammering increases the density of the metal and closes the pores, so that I have recently had a piece of gold which was put into this condition by hammering, remain nearly two weeks floating on mercury without being attacked. If the gold in this condition is heated and cooled slowly, it again amalgamates rapidly. If, however, it is cooled rapidly by plunging it suddenly into very cold water the amalgamation takes place very slowly. The same metal, after being repeatedly rapidly cooled and heated, amalgamates more readily than if it has only been treated once.

To ascertain the effect of different substances on the gold, a strip of clean gold which readily amalgamated was dipped into a solution of sulphide of ammonium, and also into one of sulphuretted hydrogen. After being withdrawn from these liquors and allowed to dry, mercury would not touch either of the pieces. The effect of grease is well known, and the greatest care is taken in most mills to keep the "quick" bright, either by rubbing or by the addition of chemicals, to such an extent in some cases that the chemicals themselves used in excess are often a cause of the very thing they are intended to prevent. All these causes, the hammering, the effect of sulphuretted waters, and also the effect of grease, occur in every mill, and probably have something to do with the losses in gold which take place there.

The effect of the different elements likely to be found with gold was also investigated. A strip of gold which would amalgamate easily was exposed to vapors of sulphur, after which it would not amalgamate. When the piece was heated in the flame of a Bunsen burner, the film of sulphide was decomposed, and the gold amalgamated readily. To test the effects of arsenic and antimony upon gold, these metals, in variable proportions, were melted with it, and it was ascertained that considerable quantities of arsenic and antimony were in the alloys. Both these alloys amalgamate very easily. Gold and arsenic, and gold and antimony, were then precipitated

together, and it was found that the precipitates were compounds of antimony and gold and of arsenic and gold; they also amalgamated readily. It has been asserted that .0004 gram of antimony to the ton of auriferous pyrites of Grass Valley, and .001 gram in that of Callao, was sufficient to prevent the amalgamation of the gold.* This seems, however, to be not quite exact, if the statement given of the conditions in which the gold is found be correct, for there does not seem to be any reason why an alloy with a much larger amount, as in the artificial compounds, should amalgamate readily, and the natural one containing so much less, refuse to do so.

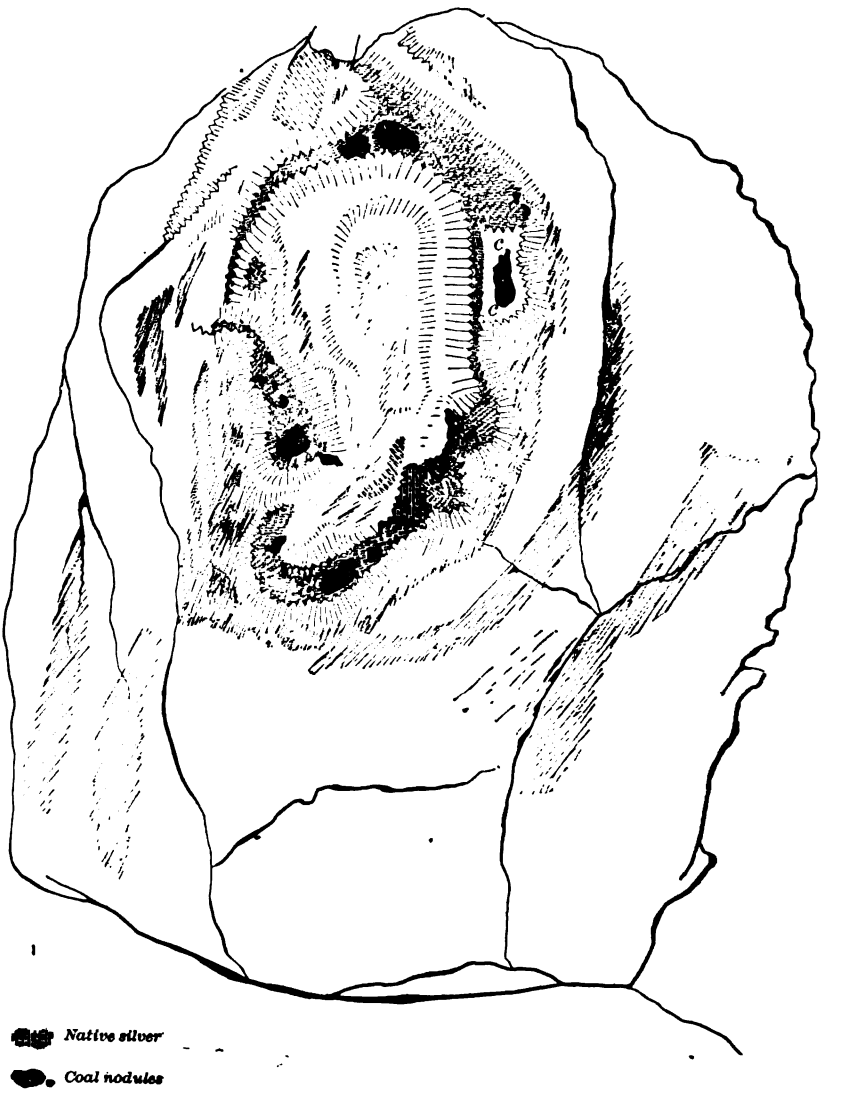
The effect of sulphur was further studied by making a regular sulphide of gold. When this was heated it was found that the sulphur was readily driven off by ignition, and the residue, which was bright-yellow gold of exactly the same shape as the sulphide, easily amalgamated. A phosphide of gold was then made by pouring melted phosphorus upon hot sponge-gold, and expelling the excess of phosphorus by heating for some time in a non-oxidizing atmosphere. It did not amalgamate. Oxide of gold was made, but this compound is so very unstable and so readily reduced to metallic gold by simple rubbing that it could not possibly have any effect on preventing amalgamation, although it is not attacked by mercury. An amalgam of gold was then placed in acid, which easily dissolved out the mercury, and left behind a brown crystalline residue of gold, which readily took up mercury again.

It will thus be seen that the stamp-mill is not a rationally-designed machine. The action of pounding is likely to put some of the gold into such a condition that the mercury will not touch it, and to flour the gold, as well as the quicksilver. There is, besides, in the mill every probability of the introduction of grease or greasy substances, like the powdered hydrated silicates of magnesia and of alumina, which not only froth but coat the gold with a slime which prevents the action of the mercury. If the water used in the mill is not pure, there is a further likelihood of the introduction of sulphuretted hydrogen, and of other soluble sulphides, which act superficially on the small particles of gold, and prevent the action of the mercury. I have elsewhere pointed out some of the other causes of losses in the treatment of gold.† The pounding action of the stamp has doubtless the effect to make some of the particles of gold wholly unattackable by mercury, while

* Comptes Rendus, March 17th, 1879.

† On the Formation of Gold Nuggets and Placer Deposits, page 633.

traced and located as the *Dexter Mine.* The accompanying rough sketch map will illustrate the topography. Future developments



Section through a quartz druse, showing the relative position of coal nodules, native silver, quartz, and calcite.

will be necessary to show whether these fissures in their downward course through the porphyry continue into the sandstone, and if so,

whether they carry the same vein-matter, notably the silver and the carbonaceous mineral.

Mineralogical Associations.—The largest specimen of vein-matter in our possession represents a full section through a vein seam 4.5 inches wide bounded by smooth walls. One of these is made up of very compact quartz from 0.5 to 0.7 of an inch wide. Upon this follows a zone of druses, almost completely filled with quartz, whose crystals protrude with fine terminations into the small internal cavities, each of the latter containing one or more nodules of the lustrous coal. The largest druse shows on the section that it is separated from the surrounding quartz by a stratum of consecutive nodules of the coal imbedded completely in massive calcite. The nodules vary in thickness from small pin's heads to 0.2 inch. This string is interrupted in one place by a cluster of crystals of native silver, some well-defined octahedrons, sitting directly upon and surrounding the carbonaceous substance (see accompanying sketch.) The quantity of native silver concentrated at this point is estimated at probably 0.1 gram.

The other wall is formed by a layer of quartz crystals at right angles to the wall surface, only 0.3 inch thick. It is separated from the inner massive quartz by another narrow zone of carbon nodules, but no silver or other metallic mineral is here met with. The mass of central compact quartz includes many small druses, each containing carbonaceous matter. Whilst thus the general law of vein formation appears well exemplified, that is, crystallization in zones parallel to the walls, there are many diagonally disposed hollows. In places the massive quartz is colored gray by minute crystals of galenite, and red by hematite, occasionally green by a little malachite. Calcite evidently was the last to crystallize, because it completely incloses the coal, which must have already assumed the shape which it now exhibits. Where the nodules of coal have fallen out, the calcite shows a very smooth surface, as if glazed, and that it was deposited rapidly is demonstrated by its compactness and the rare appearance of scalenohedral crystals.

Another specimen shows a quartz druse partly filled with coal, yellowish-brown rhombohedrons of siderite and tabular crystals of barite. This specimen shows also grains of galenite 0.1 inch in diameter, with fine cleavage planes and a gray-black film, which I take to be argentite; it is so thin, however, that sufficient material could not be got for a test.

A third specimen exhibits carbon nodules 0.5 inch in diameter,

surrounded by calcite 0.25 inch zone. In a druse of a fourth specimen, formed by very brilliant pyramidal quartz crystals, many of the latter are partly covered with pyrite crystals, most of which are changed into shapeless limonite with particles of native gold. The carbon is here not in immediate contact, and its causal connection with the gold is not established. Still another specimen exhibits galenite, tetrahedrite, and malachite, in close connection with the carbon. The malachite, it is needless to say, is the result of recent alteration of the gray copper.

Physical Properties of the Coal.—Its color is intensely black; its texture very compact; no fissures, not even capillary, can be noticed. An attempt to produce a microscopic section was unsuccessful; transparency could not be reached. Its hardness is near 2, rather above than below, but calcite readily scratches it. The substance is very brittle; breaks into very sharp and pointed splinters, with a perfectly smooth conchoidal fracture. The lustre is specially brilliant, and the streak is black. The specific gravity (here of more value than with coal generally, because of the absence of inorganic admixtures) was determined with small fragments (1.708 gr.) of the largest nodule in our possession (3.34 gr.), and the same material used in the following analyses. It was found in two trials to be 1.2486. From the number of gas bubbles which were disengaged when the fragments were boiled with water, a notable surface condensation or occlusion of gas must be inferred; this gas causes a buoyancy of the substance, so that at first the small fragments do not sink in the water.

Chemical Behavior and Analyses.—Before the blowpipe in a strong oxidizing flame splinters are scarcely affected, but the powder is slowly consumed, without leaving a residue. It does not burn with a flame. Heated to redness in a closed tube, the fragments retain their shape and even their lustre to some extent, while a distillate of slightly alkaline water and a small amount of brown oily liquid, with some combustible gas, are given off. A solution of boiling potassium hydrate does not attack the substance. Nitric acid of 1.4 specific gravity shows no action on the powder at ordinary temperature, but at the boiling temperature slowly dissolves it to a deep red-brown liquid, from which a copious precipitate of brown color is formed by the addition of water, while a nearly red liquid is produced. Hot nitric acid redissolves the precipitate. This reaction is common to all coals. The small quantity of substance at our dis-

posal prevented searching treatment with alcohol, ether, and other solvents of hydrocarbon compounds.

0.5000 gr. in a small covered platinum crucible was placed in a large platinum crucible, also well covered and heated, for thirty minutes at a faint yellow heat. A yellow flame of short duration was noticed issuing from the lid. The loss in weight was found to be 0.1384 gr. The powder had formed apparently a coke, which, however, fell to powder upon the least touch with a platinum wire. After combustion in the open crucible an inorganic residue was left, which weighed 0.0006 gr. Under the lens two or three reddish transparent fragments were seen (quartz and some brown flakes) which reacted strongly for manganese.

The result, calculated to 100, shows:

Hygroscopic water,	1.50
Volatile matter,	26.18
Coke,	72.20
Ash,	0.12
	100.00

The ultimate analysis of 0.3000 gr. gave:

0.8375 CO_2,	= 0.2284 C.
0.0970 H_2O,	= 0.0108 H.
0 0220 $(NH_4)_2PtCl_6$,	= 0 00133 N.

In these values is included the hygroscopic water = 1.66 per cent.

Sulphur was not detected.

Let now the hygroscopic water be deducted, and we have:

Carbon,	= 77.06
Hydrogen,	= 3.46
Nitrogen,	= 0.45
Oxygen,	= 18.91
Ash,	= 0.12
	100.00

The atomic ratio is C : H : O = 12.84 : 6.92 : 2.36; very nearly the empiric expression $C_{13}H_7O_2$.

Conclusions.—1. Chemically, the coal finds its place among the "sand coals," but shows less hydrogren than any of the analyses published of this class. It has no relation whatever to asphaltum, which has been observed a number of times in mineral veins.

2. Genetically, its close association with native silver is of much interest, tending to a demonstration *ad oculos* of the theory now nearly universally held by geologists, that organic substances have played an important if not exclusive rôle in the reduction of this metal from its salt solutions.

3. Chronologically, it may be deduced safely that this organic substance entered the vein after it was nearly or wholly filled by quartz, since this latter mineral has not produced an impression upon the nodules, but on the contrary these lie comparatively loosely in the druses; and that the infiltration of saturated calcium carbonate solution concluded the process of vein building by crystallizing compactly around the carbon nodules, and filling completely those druses into which it found entrance.

4. Geologically, the origin of this organic matter must unfortunately remain unsettled until explorations in depth may show its connection with Devonian coal seams, or oil sandstones, from whence vapory or liquid matter may have been carried upward by gas pressure. We are inclined to assume this hypothesis as most probable in the premises, notwithstanding the fact that in composition the coal is unlike asphaltum, the usual residuum and oxidation product of the oily hydrocarbons.

THE CONDITION OF SULPHUR IN COAL, AND ITS RELATION TO COKING.

BY THOMAS M. DROWN, EASTON, PA.

At the meeting of the Institute in New York, in February, 1880,* I described a process of determining sulphur in metallic sulphides, with especial reference to the determination of pyrites in coal. The process, as then described, is as follows: A solution of sodium hydrate, of 1.25 specific gravity, is saturated with bromine. If an excess of bromine is used it must be neutralized by the addition of a little more sodium hydrate. The pulverized mineral or coal is moistened with 25 c.c. of this solution and heated, then hydrochloric acid is added cautiously to just acid reaction. This operation is repeated with another 25 c.c. of the alkaline solution, and again rendered acid. The mixture should be kept hot. The contents of the beaker or dish are then

* Transactions, American Institute of Mining Engineers, vol. viii, p. 569.

evaporated to dryness to separate silica and taken up by dilute hydrochloric acid. The sulphuric acid is precipitated, with the usual precautions, by barium chloride. In the paper referred to, determinations by this process of sulphur in coal were given, which, although agreeing closely with one another, yet fell far short of the total sulphur in the coal, and the inference was that the sulphur not oxidized by the treatment with the bromine solution was an organic constituent of the coal, and could only be determined by a process which would oxidize the coal completely.

I am now able to give further results of the application of this process to the analysis of coal and coke. The object in view in this investigation was to determine, if possible, the effect of coking on the amount and condition of sulphur in the coal. Although the results in this regard are not as decisive as could be wished, yet many interesting facts have been noticed in the course of the work.

The coals used were from Pennsylvania and Virginia, and will be simply designated by letters. Two series of experiments were made. In the first the coke was made in the laboratory, in platinum crucibles; and in the second, "industrial coke," made in beehive ovens, was used.

In the first series the total sulphur was determined, by way of control, by fusion with alkaline carbonates and nitre; and in the second, by Eschka's method of heating the coal with calcined magnesia and sodium carbonate.

FIRST SERIES.

COAL A.

Proximate Analysis.		Analysis of Ash.	
Moisture,	0.75	Silica,	47.74
Volatile matters,	15.35	Alumina and oxide of iron,	34.17
Fixed carbon,	66.10	Lime,	7.61
Ash,	17.80	Magnesia,	0.98
		Sulphuric acid,	5.30
	100.00		95.80

The small quantity of ash used for this analysis is doubtless the cause of the imperfect result.

SULPHUR DETERMINATIONS IN COAL A.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.
By Bromine Mixture.	In residue from I. by combustion in oxygen, and absorption by solution of potassium permanganate.	In Ash from II. by fusion with sodium carbonate.	Total, sum of I., II., and III.	By direct combustion of coal in oxygen, and absorption by solution of potassium permanganate.	In Ash from V. by fusion with sodium carbonate.	Total, sum of V. and VI.	Total by fusion with sodium carbonate and nitrate.
1.660	0.640	0.040	**2.340**	1.983	0.203	**2.186**	**1.940**
1.640	0.520	0.043	**2.203**	1.768	0.329	**2.097**	**1.980**
1.670	0.563	0.026	**2.259**	1.942	0.212	**2.154**	

SULPHUR DETERMINATIONS IN COKE A.

1.073	0.747	0.065	**1.885**	1.287	0.477	**1.764**	
1.180	0.666	0.062	**1.908**	1.290	0.494	**1.784**	
1.180	0.627	0.045	**1.852**				

COAL B.

Proximate Analysis.		Analysis of Ash.	
Moisture, . . .	3.48	Silica, ...	28.89
Volatile matters, . .	25.55	Alumina and oxide of iron,	65.92
Fixed carbon, . .	66.63	Lime, ...	2.49
Ash, ...	4.34	Magnesia, . . .	0.57
		Sulphuric acid, . .	2 02
	100.00		99.89

SULPHUR DETERMINATIONS IN COAL B.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.
By Bromine Mixture.	In residue from I. by combustion in oxygen, and absorption by solution of potassium permanganate.	In Ash from II. by fusion with sodium carbonate.	Total, sum of I., II., and III.	By direct combustion of coal in oxygen, and absorption by solution of potassium permanganate.	In Ash from V. by fusion with sodium carbonate.	Total, sum of V. and VI.	Total by fusion with sodium carbonate and nitrate.
0.041	0.450	0.031	**0.522**	0.431	0.058	**0.489**	**0.474**
0.035	0.464	0.037	**0.536**	0.461	0.035	**0.496**	**0.473**
				0.454	0.053	**0.507**	

SULPHUR DETERMINATIONS IN COKE B.

0.034	0.406	0.060	**0.500**	0.429	0.087	**0.516**	**0.495**
0.056	0.400	0.063	**0.519**	0.441	0.080	**0.521**	**0.536**

COAL C.

Proximate Analysis.		Analysis of Ash.	
Moisture,	1.16	Silica,	60.94
Volatile matters,	33.08	Alumina and oxide of iron,	32.86
Fixed carbon,	61.81	Lime,	1.75
Ash,	3.95	Magnesia,	0.10
		Sulphuric acid,	2.28
	100.00		97.93

SULPHUR DETERMINATIONS IN COAL C.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.
By Bromine Mixture.	In residue from I. by combustion in oxygen, and absorption by solution of potassium permanganate.	In Ash from II. by fusion with sodium carbonate.	Total, sum of I., II., and III.	By direct combustion of coal in oxygen, and absorption by solution of potassium permanganate.	In Ash from V. by fusion with sodium carbonate.	Total, sum of V. and VI.	Total by fusion with sodium carbonate and nitrate.
0.127	0.647	0.028	**0.802**	0.693	0.036	**0.729**	**0.766**
0.139	0.631	0.022	**0.792**	0.701	0.030	**0.731**	**0.712**
				0.762	0.035	**0.797**	

SULPHUR DETERMINATIONS IN COKE C.

0.041	0.547	0.026	**0.614**	0.583	0.033	**0.616**	**0.640**
0.018	0.582	0.028	**0.628**	0.605	0.034	**0.639**	**0.650**

It has been recently stated by Mixter* that bromine-water, or a solution of bromine in hydrochloric acid, fails to oxidize all the sulphur dioxide produced by the combustion of coal, and that the vapors should be carried into a large bottle containing bromine vapors before they are allowed to escape. I have found also that a final large bromine bottle collects a very small amount of sulphuric acid after the vapors have passed through a solution of potassium permanganate. A coal containing 0.721 per cent. of sulphur gave 0.009 per cent. in the large bromine bottle, and another coal containing 0.605 per cent. gave 0.024 per cent. In the following experiments the large bromine bottle was used, and the sulphur given as absorbed by permanganate solution includes the small amount found in the bromine bottle. As stated in a previous paper, I much prefer potassium permanganate to bromine for the oxidation of sulphur dioxide or sulphuretted hydrogen.

* American Chemical Journal, ii, 396.

In the combustion of bituminous coals in oxygen explosions frequently occur. These may be avoided by simply diluting the oxygen with atmospheric air to the extent of equal volumes. The coal or coke can be best ignited in the tube in the following manner. The platinum boat containing the coal is placed just within the tube, which is then filled with oxygen. The cork is then removed, and a glowing splinter of charcoal placed in the end of the boat, which is quickly pushed into the middle of the tube. The flow of oxygen is at once resumed and the coal continues to glow until it is all consumed. The gas in the combustion-furnace is kept turned low until the coal is nearly consumed, when it is turned on to a good red heat.

In the foregoing experiments the coke was made in platinum crucibles over a Bunsen burner. To test the effect of coking on an industrial scale, I had samples taken of the coal which was put into an oven and of the coke which came out. This was not done under my surpervision, and consequently some uncertainty exists as to the thoroughness of the sampling. The following are the results obtained on three samples of coal and the corresponding coke made in ovens.

The total sulphur was directly determined in these coals and cokes by Eschka's method of heating with calcined magnesia and sodium carbonate, and oxidizing the solution in water by bromine. This is much to be preferred, in regard to simplicity and accuracy, to fusion with alkaline carbonates and nitre.

SECOND SERIES.

COAL E.

Proximate Analysis.

Volatile matters (including moisture),	24.25
Fixed carbon,	70.51
Ash,	5.24
	100.00
Ash in coke,	5.41

The ash determinations in this coal and coke indicate imperfect sampling.

SULPHUR DETERMINATIONS IN COAL E.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
By Bromine Mixture	In residue from I. by combustion in oxygen.	In Ash from II.	Total.	Direct combustion in oxygen.	In Ash from V.	Total.	Total by Eschka's method.	Iron.
0.155	0.488	0.020	**0.663**	0.721	0.044	**0.765**	**0.733**	0.32
0.156	0.478	0.017	**0.651**	0.679	0.032	**0.711**		
SULPHUR DETERMINATIONS IN COKE E.								
0.119	0.532	0.012	**0.663**	0.637	0.021	**0.658**	**0.665**	
0.125	0.533	0.013	**0.671**	0.669	0.017	**0.686**		

COAL F.

Proximate Analysis.

Volatile matters (including moisture),	29.75
Fixed carbon,	62.37
Ash,	7.88
	100.00
Ash in coke,	9.80

SULPHUR DETERMINATIONS IN COAL F.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
By Bromine Mixture.	In residue from I. by combustion in oxygen.	In Ash from II.	Total.	Direct combustion in oxygen.	In Ash.	Total.	Total by Eschka's method.	Iron.
0.349	0.560	0.014	**0.923**	0.923	0.045	**0.968**	**0.949**	0.666
0.354	0.546	0.012	**0.912**	0.905	0.043	**0.948**		
SULPHUR DETERMINATIONS IN COKE F.								
0.296	0.619	0.012	**0.927**	0.907	0.017	**0.924**	**0.917**	
0.299	0.607	0.008	**0.914**	0.913	0.024	**0.937**		

COAL G.

Proximate Analysis.

Volatile matters (including moisture),	88.01
Fixed carbon,	56.27
Ash,	5.72
	100.00
Ash in coke,	8.76

SULPHUR DETERMINATIONS IN COAL G.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
By Bromine Mixture.	In residue from I. by combustion in oxygen.	In Ash from II.	Total.	Direct combustion in oxygen.	In Ash from V.	Total.	Total by Eschka's method.	Iron.
0.129	0.588	0.018	**0.735**	0.749 0.727	0.042 0.045	**0.791** **0.772**	**0.759**	0.290

SULPHUR DETERMINATIONS IN COKE G.

0.085	0.516	0.025	**0.626**	0.581 0.605	0.050 0.016	**0.631** **0.621**	**0.597** **0·590**	

I add an analysis of anthracite, illustrating this method of treatment.

ANTHRACITE.

Analysis of Ash. (5.11 per cent.)

Silica,	50.06
Alumina and oxide of iron,	44.22
Lime,	1.39
Magnesia,	0 21
Sulphuric acid,	2.05
	97.93

SULPHUR DETERMINATIONS IN ANTHRACITE.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.
By Bromine Mixture.	In residue from I. by combustion in oxygen.	In Ash from II.	Total.	Direct combustion in oxygen.	In Ash from V.	Total.	Total by fusion with sodium carbonate and nitrate.
0.08	0.485	0.024	**0.589**	0.512 0.534	0.042 0.040	**0.554** **0.574**	**0.589**

No calcium sulphate was found in any of these coals. They were tested by boiling for some time the finely pulverized coal with water slightly acidulated with hydrochloric acid, in a flask from which the air was excluded by a current of carbon dioxide. The

precaution of excluding the air is necessary, since pulverized iron pyrites boiled with water (or solution of sodium carbonate, as has been recommended for the determination of calcium sulphate) with accese of air is readily oxidized, and the water reacts for sulphuric acid.

In the second series of analyses it will be seen that there is in each case an excess of total sulphur over what is necessary to form pyrites with the iron, and that there is not enough sulphur, as determined by bromine, to form pyrites with all the iron. This would seem to indicate that the sulphur is present in these coals, both as pyrites and as an organic constituent of the coal, and also that the iron is present, both in combination with sulphur and with silica or other inorganic constituents of the ash.

The foregoing determinations, while they are insufficient to throw much light on the effect of coking on the condition, or the elimination of sulphur in coal, may not be without value in indicating a new line of investigation of coals and cokes.

In the coal A, which contains sulphur in considerable amount, both as metallic sulphide and as an inherent constituent of the coal, and which, at the same time, is low in volatile ingredients, it would seem as if the elimination of sulphur was limited to a portion of that existing as pyrites, and that the organic sulphur, if we may so call it, was not affected by the process of coking. This becomes apparent if the percentage of sulphur in the coke is calculated on the basis of the amount of coal required to make the coke.

In the other coals, low in pyrites and higher in volatile matters, there was an elimination of the organic sulphur to the extent of 20 to 45 per cent. It would be interesting to determine the effect of different methods of coking, and of the duration of the process on this elimination.

If we admit the presence of organic sulphur in coke, it is probable that no plan for its removal could be effective which would not involve the destruction of the coke itself. In the method of analysis given, we are able to distinguish between the organic and inorganic combinations of sulphur in coke, and thus to determine the feasibility of its desulphurization.

It is interesting to note (more especially in coal A), that the ash of the coal which has been burned directly in oxygen contains much more sulphur than that from the same coal which has had its sulphur, in the form of pyrites, removed by bromine.

The analytical determinations in this investigation were made with great care by Mr. P. W. Shimer.

A SUMMER SCHOOL OF PRACTICAL MINING.

BY HENRY S. MUNROE, ADJUNCT PROFESSOR, SCHOOL OF MINES, NEW YORK CITY.

THE plan of organizing a summer class of students of the School of Mines, for the practical study of mining and miner's work, received at the outset the following cordial indorsement:

. . . . "I have thought over the plan proposed by you of taking the students to the mines during the summer, and of having them actually take part, under the direction of skilled workmen, in all the various kinds of mining work; and of using them as a corps of engineers to make inside and outside surveys, particularly with a view to the detailed study of the geology of the mine. I have no hesitation in saying, that if the students have been previously instructed in the theoretical part of their studies, by lectures and practice during the winter, the plan would be an admirable one. Of course experience will suggest modifications of detail. From the work you have done at our mines this spring, I feel sure that you would be perfectly competent to carry out your plan, and I shall gladly aid you in any way I can.

"Yours, sincerely, E. B. COXE."

The plan of the proposed summer school thus indorsed by Mr. Coxe was adopted by the trustees of Columbia College, and an appropriation of one thousand dollars, or so much thereof as might be necessary, was voted for the experiment.

A volunteer class of thirteen students was formed, and the first summer school was held at Drifton, in July and August of that year (1877). The following extract, from an editorial notice in the *Engineering and Mining Journal*, of August 11, 1877, will give an idea of the organization of the school and the work required of the students.

"The students, on reporting to Professor Munroe, were divided into squads of two or three men each, and on Monday, July 2d, were assigned to the care of skilled miners, selected for the purpose by the mine boss, for instruction in gangway work. Half of the students worked in the morning and the other half in the afternoon, one squad at a time with each miner. The times of going and coming to and from work were so arranged that each student spent four to four and a half hours in the mine each day. While in the mine they assisted the miner to load his car, thereby learning readily to distinguish 'slate' and

'bony' from good coal, even in the uncertain light afforded by their mine lamps. They were also instructed in the use of the drill and pick, boring themselves the blast-holes, judging the quantity of powder required, making up the cartridge, tamping, and firing the shot. On coming out of the mine each squad was required to make a written report of the work done, with sketches showing the location, direction, depth, etc., of each shot fired, and the effect produced.

"Four days were thus spent in the gangways learning the rudiments of miners' work, and then the students were transferred to the charge of other miners, selected by the mine-boss, working in breasts of different degrees of pitch, spending one or two days with each.

"From this time on less importance was attached to manual labor on the part of the students as a necessary part of the scheme of instruction, though most of the students of their own choice still continued to work more or less. The principal advantage gained by this manual work was the breaking of the ice between the student and the miner, placing them in pleasant relations and on common ground, the student for the time becoming, to all intents and purposes, the miner's 'butty,' and to be treated and instructed as such.

"Another advantage gained was the knowledge of the different conditions having influence on the ease or difficulty of working, and thus some idea of the value of that most variable quantity—a day's work.

"In addition to their work in gangways and breasts, the students also spent some days with other skilled miners in setting props and timbering gangways, building brattice and driving airways, laying tracks and putting in switches on mine roads, in getting coal by robbing, in artesian-well boring for water, boring by hand for exploration, etc.

"After the students had spent in this way about twenty days at different kinds of work underground and in the 'breaker,' subjects for more detailed study and investigation were assigned them. Each student having chosen his theme, spent the remainder of his time in collecting material for a memoir. 'Underground Haulage,' 'Ventilation,' 'Mine Pumps,' 'Hoisting Engines,' 'Winning of Coal in Breasts of Different Degrees of Pitch,' 'Artesian-well Boring,' 'Breaking and Sizing of Anthracite,' 'Separation of Slate from Anthracite,' 'Water-supply for Boilers and for Household Use, and Washing of Coal,' etc., were among the subjects thus assigned.

"During the last few days trips were made to several mines in the vicinity, at Hazleton, Ebervale, etc., spending a day underground in each case with the mine-bosses, who explained in detail the characteristics of their mines and their methods of working. Mr. Coxe, also, during their stay, gave the students several informal talks of great practical value on the mining of anthracite, installation of machinery, management of men, necessity for scientific bookkeeping, discussion and analysis of mine accounts, etc.

"The miners and the mine-bosses of the Cross Creek collieries have taken great interest in the experiment, and to their cordial and hearty co-operation in the carrying out of all the details of the plan is due in no small degree the very gratifying success attained.

"It is, however, to the interest taken by Mr. Eckley B. Coxe in this new departure in mining education that its success is in a large measure due, for he not only encouraged the idea when proposed, but placed his collieries—probably the finest in this country—at the service of the school, and gave such instructions as secured for the student a favorable introduction to the miners.

"One of the most notable and prominent features of this effort to introduce the

practical element into the studies of the School of Mines has been the demonstration that the students are not 'a nuisance' about the works, but, on the contrary, are welcomed by the miners, and are found to make no trouble or interference with the work of the colliery."

The experiment having proved successful, the trustees of the college voted to make the summer class a part of the regular course of study for the degree of Mining Engineer.

The next summer (1878) the school was held at Mineville, N. Y., at the large magnetite mines of Witherbees, Sherman & Co., and of the Port Henry Iron Ore Company.

The session of 1879 was held in the copper regions of Lake Superior, with headquarters at the Atlantic Mine, near Houghton.

Last summer (1880) the field of operations was enlarged, and the time devoted to practical work was divided between the Dickerson Mine (magnetite) of the Musconetcong Iron Company, near Dover, N. J., and the mines of the Westmoreland Coal Company, near Pittsburgh.

This summer (1881) the time will be divided between the copper mines of Keweenaw County and the iron mines of Marquette County, Michigan.

The plan of work, as it has developed itself in these four sessions of the school, begins with a detailed study on the part of each student of the plant and methods of working at the mine selected for the summer school. The students for this purpose are divided into squads of two or three men, and each squad is assigned to the care of a skilled miner and given each day some one subject for observation and study. To aid the student in systematizing his work, and to suggest lines of investigation, he is provided with a printed scheme of study, which he is expected to follow in making out his daily reports.

The following scheme of study was used last summer at the Dickerson Iron Mine.

DICKERSON MINE, FERROMONT, MORRIS COUNTY, N. J., June 14th, 1880.

Each student of the summer school will be required to make the following reports:

1. *Hand-drilling and Blasting.*

Description from actual observation, of the method of blasting in driving a cross-cut or drift. The report will include:

1. A description of the tools employed, illustrated by careful sketches, half size, showing form and dimensions of each tool.

2. The time of boring, number and size of drills used, and the position, direction, and depth of each hole. To be illustrated by drawings of the heading of the drift or cross-cut, on a scale of one-twentieth, showing in three projections

the position and direction of each hole bored. Holes bored during the night shift, or in the absence of the student, should be drawn in dotted lines, and the order in which the holes were bored should be indicated by numbering them.

3. The kind and amount of powder and of tamping used in each hole, and method of charging, tamping, and firing.

4. The reasons for the location and direction of each hole, and the work intended and actually performed by the blast. The failure of any blast to do the work expected, and holes which for any reason have to be abandoned, should be carefully noted, with the reason for such failure or abandonment, if possible.

5. The number of men employed at the work and duties of each; number and length of shifts; amount driven during previous months, and average progress of drifts; number of drills, hammers, shovels, and other tools required, average number of drills sharpened per day, wear of steel, consumption of powder, oil or candles, etc.

2. *Stoping of Ore.*

Description, from actual observation, of the methods of stoping, including the preparatory sinking or drifting, and the breaking of the ore by machine or hand-drilling and blasting; illustrated by sketches of the stope in horizontal projection, with longitudinal and cross-sections.

Sketches on a scale of one-twentieth, showing the location, direction, and depth of several consecutive blast-holes, with description in detail of the boring, charging, tamping, firing of each hole.

3. *Machine Drills.*

Description of machine drills, size, weight, pressure of air, and size and shape of drilling-bits, etc.

Description of the work of boring one or more blast-holes, including setting of machine, starting of hole, feeding of drill, changing of bits, etc. Give time of each operation, noting delays and their cause. Number of holes and total depth bored per shift. Number of drills blunted per day. Wear of steel.

4. *Timbering.*

Description and sketches of the different forms of timbering used in the mine, stulls and lagging, studdles, etc.

Sketches of details of skip-roads, showing different methods of supporting track-timbers and ladders on stulls, etc.

Sketches of timbering of slope and of shafts. Supports of ladders and pump-rods, details of landing-stage and sollars.

Arrangements for protecting men, machinery, etc., from blasts and falling rock—batteries, pentice, etc.

Description and measurement, illustrated by careful sketches and from actual observation, of the work of putting in one or more stulls; including cutting of hitches in rock, measuring and cutting timber, lowering of timber from surface and handling it in the mine, arrangement of tackle and hoisting of timber to place, and wedging.

Kinds of timber used, whence obtained; seasoned *vs.* green timber; stripping of bark; renewal of timber, etc

5. *Pumps.*

Details of pumping engines and of pumps, stroke, diameter, speed, valve motion, etc. Sketches of pumps, pump-rods, bobs, and methods of changing

direction of rods. Manner of connecting and supporting rods. Use of plunger, and of lift or jack-head pumps. Repair and packing of pumps. Pumps, location and size. Gallons of water pumped per day. Use of steam pumps in the mine, support and covering of steam-pipes, disposal of exhaust steam.

6. *Handling of Ore.*

Description of the method of handling ore in the stopes, including the getting down of ore after a blast with pick or bar, the breaking up of large masses by block-holing or sledging, sorting of ore from rock, loading of cars or barrows, dumping into skips, etc. Sketches of tram-car, loading platform and chute, details of track, turnouts, and switches, etc.

Description of hoisting engines, dimensions, speed, steam pressure, valve motion, gearing, etc. Construction of hoisting drum, diameter, length; number of revolutions per minute, and to hoist from bottom. Description of brake. Size and character of wire rope. Tell-tales and signals. Number of skips of ore hoisted and of timber lowered per day. Speed of buckets, skips, or cars. Sketches of skip, and self-dumping devices. Sketches of sheaves, and of guide rollers for wire rope, on surface and in the mine.

Handling of ore on the surface, loading of cars, breaking, cobbing, and hand-picking. Transportation to market.

Handling and disposal of waste rock underground, and on the surface.

Sketches of whims, poppet-heads, and other surface constructions.

7. *Surface Works.*

Sketch map showing relative position of surface works, shafts, tunnels, engine and boiler-houses, shops, change-house and other buildings; railroad tracks, switches, turnouts, etc., tramways; lines of steam, water, and air-pipes, and of surface drainage. Description of above buildings, roads, etc., and notes on source of water-supply for boilers and for household use. General description of miners houses, number, internal arrangements, etc. Plans of change-house, shops, and other buildings.

8. *Shops.*

Sketches showing arrangement of blacksmith-shop, machine-shop, carpenter-shop, etc. Description of the method of sharpening and tempering drills, picks, etc. Sharpening and repairs of bits of machine drills. Work of machine-shop, repairs to pumps, rock drills, and other machinery. Carpenter-shop, making of ladders, tram-cars, and miscellaneous repairs. Number of men required, etc.

The following scheme of study was prepared for the use of the students at the mines of the Westmoreland Coal Company after the completion of their work at the Dickerson Mines.

WESTMORELAND COAL MINES, IRWIN'S STATION,
WESTMORELAND CO., PA., July 12th, 1880.

Each student of the summer school will be required to make the following reports:

1. *Shaft Sinking.*

Description, from actual observation, of the method of blasting in sinking a shaft. The report will include:

1. A description of the tools employed, illustrated by careful sketches, half size, showing form and dimensions of each tool.

2. The time of boring, number and size of drills used, and the position, direc-

tion, and depth of each hole. To be illustrated by drawings of the bottom of the shaft, on a scale of one-twentieth, showing in three projections the position and direction of each hole bored. Holes bored during the night shift, or in the absence of the student, should be drawn in dotted lines, and the order in which the holes were bored should be indicated by numbering them.

3. The kind and amount of powder and of tamping used in each hole, and method of charging, tamping, and firing.

4. The reasons for the location and direction of each hole, and the work intended and actually performed by the blast. The failure of any blast to do the work expected, and holes which for any reason have to be abandoned, should be carefully noted, with reason for such failure or abandonment, if possible.

5. The number of men employed at the work and duties of each; number and length of shifts; amount sunk during previous months; and average progress of the sinking; number of drills, hammers, shovels, and other tools required, average number of drills sharpened per day, wear of steel, consumption of powder, oil or candles, etc.

2. *Drifting.*

Description of the method of driving entries, "bearing in" or undercutting, "shearing," and wedging. Main entries and cross entries; entries on the "face" and on the "end" or "butt" of the coal; advantages of double entries. Crosscuts or "cut-throughs." Section, to scale, of the coal seam, showing the "bearing in" seam and the different slate partings. Inventory and sketches of tools used in driving. Description of work, number of men required, length and number of shifts, progress of work per shift and per month. Time required for each operation, undercutting, shearing, breaking down, loading, taking up bottom coal, laying track, etc.

3. *Mining of Coal.*

Description of method of getting coal in the rooms. Sketch, to scale, showing plan of room, with track, posts and slate heap, stump, ribs, etc. Breaking down of coal by wedges or powder after undercutting and shearing. Precautions necessary for safety. Manner of conducting the work so as to make a minimum of fine coal or dirt. Separation and disposal of slate and fine coal. Number of cars loaded per day, etc.

Getting of coal by robbing. Sketches showing method of attacking ribs, with subsequent robbing of stumps and pillars. Description of the work and precautions used for the safety of the men and to avoid loss of coal. Number of men, length of shifts, and amount of coal obtained and lost.

4. *Ventilation.*

Sketch map showing the course of the air through a section of the mine, location of doors, stoppings, brattice, crossings, etc. Sketches showing construction of fans employed, and the passages by which they are connected with the airways of the mine. Arrangement for reversing the ventilating current. Description and sketch of ventilating furnace. Details of doors, stoppings, brattice, air-boxes, etc. Methods of measuring air and regulating and dividing air-current. Résumé of ventilation law, with object of different requirements.

5. *Drainage.*

Description of the different methods of draining the mines. Ditches in entries; grade required, etc. Special water-courses. Draining of "swamps" by siphons, pumps, or water cars Pumping of acid waters and method of protecting water-column and the working parts of the pumps from the action of the acid.

6. *Timbering.*

Timbering in shafts, entries, and rooms. Sketches showing arrangement of timbers, manner of notching and wedging, etc.

7. *Underground Haulage and Shipment of Coal.*

Description and sketches of cars, size, weight, capacity, etc. Description of different kinds of track used, width of gauge, size and weight of strap iron or rails, etc. Switches and crossings. Maximum and minimum grade of track in main and cross entries. Hauling by mules and locomotives, number of cars hauled at once on different grades and on different tracks. Organization of trips.

Description of hoisting engines, dimensions, speed, steam pressure, valve motion, gearing, etc. Construction of hoisting drum, diameter, length, number of revolutions, and time required to hoist from bottom. Speed of cage. Description of brake. Size and character of wire ropes. Tell-tales and signals. Number of cars hoisted per day. Sketch of cage, showing safety catches, hood, means of holding car on platform, etc.

Description and sketches of arrangements for screening and weighing the coal and for the loading of railroad cars. Transportation to market.

8. *Surface Works and Shops.*

Sketch map showing relative position of surface works, entries, shafts, engine and boiler houses, shops, change-house and other buildings; railroad tracks, switches, turnouts, etc., tramways; lines of steam, water, and air pipes, and of surface drainage. Description of above buildings, roads, etc., and notes on source of water-supply for boilers and for household use. General description of miners' houses, number, internal arrangements, etc. Plans of change-house, shops, and other buildings.

Sketches showing arrangement of blacksmith-shop, machine-shop, carpenter-shop, etc. Description of the method of sharpening and tempering drills, picks, etc. Work of machine-shop, repairs to pumps, and other machinery. Carpenter-shop, making of tram-cars and miscellaneous repairs. Number of men required, etc.

About four weeks was required for the detailed study indicated in these schemes. By this time the student is familiar with the ordinary routine of mine work, having spent from two to four days each with the miners engaged in sinking, drifting, stoping, and timbering, making sketches and taking notes under ground, and each afternoon or evening reviewing carefully the work of the day as he makes out the required report. In a similar manner he has exam-

ined and studied the plant connected with the mine, pumps, engines, etc., the timbering in the shafts, slopes, and gangways, the shops and other surface works, and has followed the coal or iron ore from the time it is broken down by the miner, till it is finally loaded on the railroad cars.

This careful and detailed examination of one mine finished, the student is prepared with the information and insight thus gained to visit other mines in the same district, for the purpose of studying variations in practice, and differences in plant and methods of working, by comparing similar work as carried on in other mines and under different conditions. A week or ten days is, therefore, devoted to excursions to neighboring mines.

Finally, each member of the class has assigned him a subject for a memoir, either the description of the plant and workings of some mine, or the machinery and methods of a stamp-mill or dressing works, or some general subject connected with mining. In most cases he is instructed to describe in greater detail some one or more machines or methods peculiar to the place. In collecting the data for this descriptive memoir the student spends about two weeks at one mine, or in visiting different mines, as the subject assigned him may require; the class being divided into small parties, not more than two or three men at a mine. The memoirs are illustrated by sketches, tracings, and working drawings, and have in most cases been compiled with great care. They are often exceedingly interesting and valuable, containing much material descriptive of plant and methods of working at the mines visited.

Under this plan of work it will be seen that the student makes a careful and detailed study of at least two mines, at first with the class and under the instruction and superintendence of the professor, and afterwards at another mine by himself, in collecting the data for his memoir. The excursions and visits to other mines supplement this detailed study, and give the student a wider view of the practice of the whole region.

ON THE USE OF SALT COATING IN THE MANUFACTURE OF IRON AND STEEL WIRE.

BY CHARLES H. MORGAN, WORCESTER, MASS.

THE process of wire drawing depends upon the property which certain metals possess, termed ductility, which is defined in Brande's Dictionary of Science as a property in consequence of which metals may be drawn out at length without interrupting the continuity of their constituent parts. As defined by M. Tresca, it is the property of flowing when subjected to pressure, and is termed by him the "flow of solids," in his paper, read before the Academy of Sciences in Paris, November, 1865.* In the simple language of the wire shop, it is that quality in certain metals that permits them to be drawn (or stretched) out through a tapering hole in a metal block or die, the die being more dense and harder than the metal to be reduced.

It is a fact well known to those skilled in the art, that to succeed in drawing iron or steel wire, it is of the utmost importance to have thorough lubrication, as a lack of it would cause abrasion of the wire, or of the walls of the tapering hole in the die or plate, and quickly put an end to the operation.

In drawing coarse or large sizes of wire, say $\frac{2}{10}$ inch diameter, the pressure upon the sides of the tapering hole, where the wire comes in contact with the die, is so great that an ordinary lubricant is squeezed out when the usual reductions in size are made, and abrasion takes place. In order to meet this difficulty, and secure proper lubrication, it has been a common practice for years to apply a paste made of rye or wheaten flour, or lime, to the surface of the wire to be drawn, and when the paste is dry, to smear the wire with tallow or grease; the wire is then ready to be drawn, the dried paste serving to prevent the lubricant from being pressed out in the process.

Some years since, when Bessemer metal came largely into use as material for wire, the writer found that its drawing required so much more power than iron wire, that he was led to institute a series of trials to ascertain the difference in power required. It was found that Bessemer wire required from 100 to 200 per cent. more power to make the same reduction in sizes than soft iron wire, the difference depending upon the amount of carbon and other chemical constitu-

* Interesting experiments in the flow of metals have been made by Messrs. Hooper & Townsend, of Philadelphia, in cold-punching iron, published and illustrated in the Journal of the Franklin Institute, of March, 1878, by Mr. David Townsend.

ents. The diagrams and tables accompanying this paper will indicate the nature of some of the trials alluded to.

The failure of the coatings in common use in drawing Bessemer wire led to the inquiry: Is there not some coating that will endure this increased pressure? and trials were made at the works of the Washburn & Moen Manufacturing Company, at Worcester, Mass., to ascertain if something could be found which, in combination with the flour or lime paste, would adhere with sufficient tenacity. Early in 1878, while two young men were making, with discouraging results, trials of various substances to modify the lime coating, one of them said to the other, "If I wanted to make whitewash *stick*, I would put some salt in it; let us try it." Whereupon salt was used and found to make the whitewash stick, but it was also found that unless the wash was quickly dried on the wire, and kept dry, the wire would be corroded with rust. Soon after it occurred to the writer to use a hot solution of lime and salt, and it was found that, by using the solution at a boiling temperature, the water was quickly thrown off, when the wire was taken from the bath, and it was only necessary to keep the wire in a warm, dry place till it was drawn. Salt coating, whether combined with lime or otherwise, has been found to resist any pressure that steel wire of the highest tensile strength makes, when being drawn, upon the inner surface of the die.*

The following table shows the power required in drawing wire when salt coating is used:

TABLE I.

Showing Power Required in Wire Drawing.

	I.	II.	III.
Diameter of wire before drawing, inch, .	0.224	0.226	0.224
Diameter after drawing, inch, ...	0.191	0.197	0.192
Area before drawing, square inch, . . .	0.394	0.401	0.394
Area after drawing, square inch, ...	0.286	0.301	0.289
Reduction, per cent., ...	27.3	24.9	26.6
Length of taper of wire in die, ...	0.280	0.290	0.340
Power to draw wire, lbs., ...	1.060	3.054	3.450

* Compare a paper by Prof. C. O. Thompson, "On the Action of Common Salt and other Related Crystalline Salts in Wire Drawing," page 299.

Composition of the Wires.

	I.	II.	III.
Phosphorus,	0.034	0.144	0.114
Sulphur,	0.006	0.052	0.025
Silicon,	0.031	0.068	0.209
Manganese,	0.399	1.040	0.461
Carbon,	—	0.450	0.869

Sample No. I. is soft Swedish iron.
" No. II. is American Bessemer steel.
" No. III. is American Crucible steel.

FORMULAS.

Showing Approximately the Relation between Quantities Involved in Wire Drawing.

V = Velocity of wire before entering the draw plate or die.
D = Diameter of wire before entering the draw plate.
A = Sectional area of wire before entering the draw plate.
v = Velocity of wire after leaving the die.
d = Diameter of wire after leaving the die.
a = Sectional area of wire after leaving the die.
v_x = Velocity of a section of wire inside of the die.
d_x = Diameter of this section.
a_x = Area of this section.
Δ = An element of the tapered surface in contact with the wire.
p = Mean pressure per square inch on the tapered surface.
P = Total pressure on tapered surface.
l = Length of taper of wire in the die, = (nearly) length of centre line.
Q = Total force acting on the wire in direction of motion.
a° = Angle between the tapered surface and centre line of wire.
V_m = Mean velocity of the whole rod in passing through the die.
f = Coefficient of friction in the die.

Fig. 1.

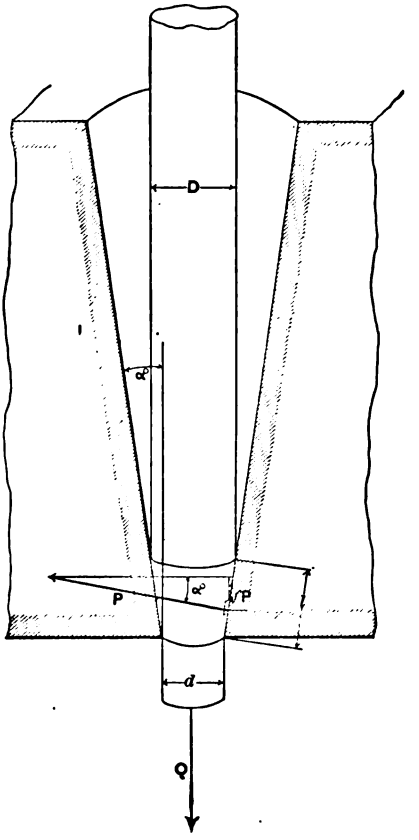
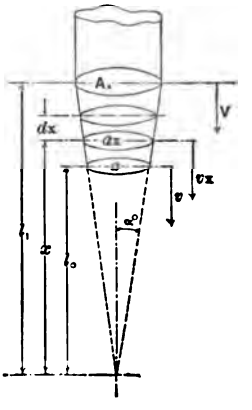


Fig. 2.



Assuming the same density for different parts of the rod, we have

$$VA = v_x a_x = va \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 1.$$

Calling V_m the mean velocity of the whole rod, we obtain from fig. 2

$$V_m = \int_{l_0}^{l_1} \frac{v_x\, dx}{l_1 - l_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 2.$$

From equation 1 we have

$$v_x = \frac{VA}{a_x}$$

and by substituting this value of v_x in equation 2, we obtain

$$V_m = \frac{VA}{l_1 - l_0} \int_{l_0}^{l_1} \frac{dx}{a_x} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 3.$$

We have furthermore from fig. 2

$$\frac{a_x}{A} = \frac{x^2}{l_1^2} \text{ and } a_x = \frac{Ax^2}{l_1^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 4.$$

And by substituting this for a_x in equation 3, we obtain

$$V_m = \frac{Vl_1^2}{l_1 - l_0} \int_{l_0}^{l_1} \frac{dx}{x^2} = \frac{Vl_1^2}{l_1 - l_0} \left\{ \frac{1}{l_0} - \frac{1}{l_1} \right\}$$

or

$$V_m = V \frac{l_1}{l_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 5.$$

At last from fig. 2 we have

$$\frac{l_1}{l_0} = \frac{D}{d} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 6.$$

and by substituting in 5

$$V_m = V \frac{D}{d} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 7.$$

Taking the work done in consideration, we obtain from fig. 1

$$P (\sin \alpha + f \cos \alpha)\, V_m = Qv \quad . \quad . \quad . \quad . \quad . \quad 8.$$

And by substituting in this the value V_m as found in equation 7, we have

$$P (\sin \alpha + f \cos \alpha)\, V \frac{D}{d} = Qv;$$

from equation 1 we have

$$v = \frac{VA}{a}$$

and by substituting this in the above we obtain

$$P(\sin a + f\cos a)\frac{D}{d} = \frac{QA}{a}$$

But $$\frac{A}{a} = \frac{D_2}{d_2};$$

hence, by substituting in above equation we obtain

$$P(\sin a + f\cos a) = \frac{QD}{d} \quad \ldots\ldots 9.$$

From fig. 1 we have

$$\sin a = \frac{D-d}{2l} \quad \ldots\ldots 10.$$

and $$\cos a = \sqrt{1-\left\{\frac{D-d}{2l}\right\}^2} \quad \ldots\ldots 11.$$

By substituting the values of sin a and cos a from equations 10 and 11 in equation 9, and by a slight transformation we have

$$P = \frac{QD}{d\left\{\frac{D-d}{2l} + f\sqrt{1-\left(\frac{D-d}{2l}\right)^2}\right\}} \quad \ldots\ldots 12.$$

The following Table II. is obtained by assuming the coefficient of friction and substituting this and the numerical values as obtained from Table I. in equation 12:

TABLE II.

	LBS.	I.	II.	III.
Coefficient of friction $f = 0.00$	p =	115,647	325,952	386,782
	P =	21,105	62,745	85,886
	fP =	0	0	0
" " " $f = 0.10$	p =	42,924	115,660	123,442
	P =	7,833	22,264	27,404
	fP =	783	2,226	2,740
" " " $f = 0.15$	p =	32,607	88,969	92,092
	P =	5,951	17,126	20,444
	fP =	892	2,569	3,066
" " " $f = 0.20$	p =	26,337	71,709	72,522
	P =	4,806	13,804	16,100
	fP =	961	2,760	3,220

[For the above formulas I am indebted to Mr. Carl Angstrom and Prof. G. I. Alden.]

*COPPER REFINING IN THE UNITED STATES.**

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THE materials containing copper which are refined in the United States, are, for the most part, the native coppers of Lake Superior. Until quite recently but little pig copper was made for sale, and that came principally from the pure sulphurous ores of New England and the South, and was generally sold to refineries not far from the ore furnaces. A small amount found its way into the market which was produced either as the by-product of the treatment of gold and silver ores, or as the result of the treatment of impure copper ores; but both these grades, on account of the impurities they contained, were looked on with suspicion, and were not sought for. All the grades of pig copper are sold by the unit of copper contents, a great reduction being made in the price when impurities are present.

There are at the present time only three works which treat native copper, the two of the Detroit and Lake Superior Copper Company, and the works of C. G. Hussey & Co., in Pittsburgh. There are a few works which smelt sulphurous ores and refine their pig; besides these there are a few small works where pig copper is refined only. Some of these purchase black copper, refine scrap, or simply refine such grades of ingot copper as are found in the market, but mostly that from Lake Superior, for the purpose of getting it into such shapes that can be handled commercially to advantage, such as in making large plates or high grades of wire for electrical purposes. A number of such works are situated in the Naugatuck Valley and elsewhere in New England. The recent discovery of valuable ores in Arizona makes it probable that within a few years the refining of copper in the United States will make great developments.

Up to the time of the discovery of the mines on Lake Superior, only a very small quantity of native copper had ever been found, not sufficient to justify the erection of works for its special treatment. It had, besides, never been found in very large masses, so that the discovery of great blocks of it presented serious difficulties, not only in mining it,† but in bringing it into a merchantable condition. It seemed a very simple process to melt these large masses,

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† Transactions American Institute Mining Engineers, vol. vi, page 252.

but when it was tried it was found that even when they were reduced to pieces weighing not more than a ton each, it was exceedingly difficult to get them into the furnace. As the material was considered to be pure copper, it was thought that the single operation of melting was all that was required to make good merchantable copper; but it was found very difficult to melt the masses, when they were in the furnace, and with the best methods and appliances known, so much oxide of copper was formed and absorbed that it was necessary to refine, even though the copper charged in the furnace consisted, as it did, mainly of pure copper. Such a large loss in the slags resulted from the treatment, that the commercial solution of the problem seemed almost hopeless. It is to-day more profitable for the Calumet and Hecla to mine and smelt a four and a half per cent. rock than for the mass mines, which sometimes have blocks of hundreds of tons of nearly pure copper, to extract and smelt these masses.

The history of the attempts to smelt the ores of Lake Superior has never been written, and although it is only a little over thirty years since the first successful attempts were made, it is not easy to collect accounts of these experiments. I have therefore been at some pains to gather them in order to put on record the steps which have led to the present process.

It was supposed at the first that the large masses of copper which were found on Lake Superior must be treated like the large masses of condemned iron castings, and that they must be fused in a reverberatory furnace; but the difficulty was to get the pieces, which were exceedingly irregular in shape, into the furnace. No doors that could be built would answer the purpose, so in 1847 the works at Baltimore built a reverberatory furnace with one side almost entirely open and a small door on the other. The large masses of copper were introduced on the open side, and pulled into the furnace by attaching chains to them which passed through the small door on the opposite side, and were there attached to a capstan. The charge once in the furnace the side was built up and the operation of melting was conducted as for iron. It was however found, as the result of this method of charging, that the hearth, which should be smooth, was always more or less torn up by the uneven masses pulled over it, and even when it was protected by wood or small ore, was so much damaged as to seriously impede the operation of melting and refining. The attempt to treat the copper in this reverberatory furnace was therefore abandoned after a few months' trial, not only on account of the expense of charging the furnace and the labor of repairing the hearth, but also from the uncertainty of having a proper hearth after it was charged.

In 1848, before the works of C. G. Hussey & Co. were built, a charge of four or five tons was melted at the Fort Pitt Foundry in Pittsburgh in an ordinary cannon furnace, by taking down the side of the furnace and building it up after the charge was in. The copper was then cast in pigs in a sand bed. In order to be sure of getting all the copper into the pig bed it was built on trestle-work. As the experiment was made in the presence of an excess of air, a large quantity of slag was formed, at the expense of the sides of the furnace, which was very rich in copper, as the hearth was prepared for cast iron, and not adapted for copper. The result of the smelting was the formation of black copper, which had to be refined, and the whole furnace had to be torn down to get the rich slag out. After one attempt it was so manifest that this style of cannon furnace could not be used that no further efforts were made in this direction. It was then proposed, and gravely attempted, to smelt the masses of copper in a shaft furnace by suspending them with iron chains in the centre of the furnace. Of course the chains broke long before the copper was melted, so that the mass fell to the bottom, bursting out the sides of the furnace. As the result of these experiments the smelting of masses of copper, unless cut into very small pieces (an expense which the price of copper did not justify), was considered one of the questions almost too difficult for solution.

Early in the year 1848, after the discovery of the Cliff Mine, and before any other of the Lake Superior mass mines were worked on a large scale, Dr. C. G. Hussey, of Pittsburgh, one of the owners, and a director of the mine, endeavored to have the masses smelted at the Revere Copper Works at Boston. They found the ore so difficult to treat at these works that they charged $80 a ton for doing it. The attempts previously made to treat it at Baltimore and elsewhere had met with so little success, that it was finally seriously proposed to smelt the masses with sulphur, or sulphurous ore, to reduce the metallic copper to a matte, which, however, was never done.

Dr. Hussey determined to make the attempt to treat the ore at Pittsburgh, and, learning from a German that large furnaces with movable roofs, supported by a crane, had been built in Germany for the cupellation of silver-lead, engaged, in company with T. M. Howe, in the spring of this year (1848), two smelters, William and Henry Johns, of Swansea, Wales, to build in Pittsburgh, for the Pittsburgh and Boston Mining Company, two English reverberatory furnaces similar to those used in Swansea for refining copper, but with movable roofs, and a cupola furnace, such as they now use for the treat-

ment of the slags, which they did in that year. The reverberatory furnace then built was in every respect similar to that now used by C. G. Hussey & Co., on the Monongahela River, except that it was larger, as there was then a great supply of ore, and the first casting was in every respect as good as those now made. Similar furnaces were afterwards built by Dr. Keener at Baltimore. Some years later, about 1850, the Detroit and Lake Superior Copper Company was formed, and after coming to Pittsburgh to see the furnaces used there, built theirs after this model. They met at first with but indifferent success, but finally absorbed into their company all the other works at Hancock, and enlarged their own works at Detroit. In 1850 J. G. Hussey & Co. built works in Cleveland, which were in successful operation until the fall of 1867. In 1858 Park, McCurdy & Co. erected two ten-ton furnaces, after the Hussey plan, and two small ones of three tons capacity, for scrap, exactly like those now used there for scrap. The large one ran about two years on ores from the Copper Falls and other mines, and was abandoned for want of material to smelt when the Detroit and Lake Superior Company enlarged their works. They used a Mackenzie furnace for the slags. The test of the slags was to break and rub the pieces together, doing this frequently, and judging by the eye if copper was present. In December, 1862, Park, McCurdy & Co. erected a Siemens regenerative furnace* for refining copper, of five tons capacity, which worked very successfully, but finding no ores available since the erection of the works at Hancock, and also finding that one week's work would refine all the scrap and old copper they were likely to use for one or two months, they decided that it did not pay to let the furnace go out so often, and therefore abandoned it. No other Siemens furnace has to my knowledge been built for this purpose in the United States. All of these works, except those of C. G. Hussey & Co., and those of the Detroit and Lake Superior Company, gave up the use of these furnaces when the last two works absorbed the product of the Lake district.

The smelting of the slags was first introduced in Pittsburgh in the year 1851, by Warren Billings, who procured some from a waste pile and smelted it secretly, but afterwards disclosed his process for a large consideration. The slags had up to this time been thrown away, as too difficult to treat; but judging from previous experience in copper smelting that these slags must contain a large quantity of copper, they were secretly procured by small boat-

* This is believed to have been the first Siemens furnace erected in the United States.

loads at a time, from the dump-pile on the river, and treated in a small experimental furnace erected in his yard. The success of the enterprise first became known by an offer to purchase the slag-piles, and a contract was then made for the treatment of the slag in a cupola furnace, which was essentially the same as that now used.

From these simple beginnings both the furnaces and the methods have been improved until it is doubtful whether copper is better refined anywhere than in the United States. The quality of the product is, it is true, owing in large measure to the great purity of the material used, but it is, nevertheless, true that American copper commands the highest price in the market.

Though they were not the first refineries erected, the works of the Detroit and Lake Superior Company were among the first built, and are now the most important ones in the country. Almost all the experiments and improvements which have been made in copper refining in the United States, since the method was first started in Pittsburgh, have been made there. The description of the process which is given does not apply to them exclusively, however, though many of the details and most of the drawings were taken from there, as the method in all the works is generally the same; but most of the samples analyzed were taken from the works at Pittsburgh.

The works of the Detroit and Lake Superior Copper Company are composed of two different establishments, one situated below Detroit, on the Detroit River, and the other at Hancock, on Portage Lake, opposite the town of Houghton. Together they have twelve reverberatory furnaces, eight at Hancock and four at Detroit, and five cupolas, three at Hancock and two at Detroit. They treat the stamp and mass copper for all but one of the mines both in the Keweenaw and Ontonagon districts. Seventy-five per cent. of the copper is smelted at Hancock and the rest at Detroit.

The works at Hancock (Plate I) are contained in a series of buildings parallel to the water front. The furnace houses are constructed of stone; the other buildings are of wood. There are two furnace houses containing four reverberatories each, and at the end nearest the Quincy property, three cupolas for the treatment of the slags. The whole front of the property is a series of wharves where any vessel that can enter the Portage River may dock. The plan shows the general arrangement of the works and all the cranes, shops, and buildings connected with them. At Detroit the works are constructed in two buildings, which run together in the shape of an L. The dock is about 250 feet long, having frontage on the Detroit River. On the water front are two cranes for lift-

ing the heavy masses. The rest of the dock is devoted to the storage of "mineral," and to the ingot copper which is waiting transportation to market. In front, on the end of the L toward the river, are the two cupolas for treating the slags. Behind these are the engine-room and crusher, with an open space for storage of material. Behind the engine-room is the blacksmith's shop, and then a building with two large furnaces; on the other side, separated by a short distance, is another building with two more furnaces. At both works the cupolas are modified Mackenzie's, which have been altered to suit the exigencies of the treatment of copper slags. The reverberatory furnaces treat from nine to ten tons in twenty-four hours. There is sufficient frontage on the Detroit River and on Portage Lake to dock all the steamboats and vessels which arrive with supplies or carry off the products of the works. It would seem bad policy to have part of these works at Detroit and part at Hancock. The reason why they are so situated is owing to the fact that they existed at both places, owned by different companies, and were afterwards consolidated in one interest. The ore must be shipped to Detroit from the Lake; the fluxes and the coal are near at hand, and can easily be obtained by rail or by water. A supply of the latter can, therefore, be had at all seasons, but the ore can only be had during the season of navigation, which is not more than six months in the year. At Hancock all the flux and coal must be transported long distances, and a stock accumulated sufficient to last the whole winter season; but a sufficient stock of mineral can always be had to insure the running of the furnace, the ore being close by. It would seem that Hancock would have the advantage, since it is so near the supply of ore; but at Detroit the principal part of the expenses not in common to both places is the freight on the mineral, part of which would in any case have to be borne by the copper if produced at Hancock. The amount of crude material which is not copper, carried to Detroit, is comparatively small, so that it is actually cheaper to smelt at Detroit than at Hancock. The works at Hancock are situated on a narrow strip of land between the Lake and the hill, with no possibility of extension, being shut in on one side by the hill, on the other by the water, at one end by the Quincy property, and at the other by the Franklin. They still have room here, however, to increase their smelting capacity, but it seems to be only a question of time when competing railroads shall have made transportation cheap, and the works at Hancock shall have reached their limit of capacity, that they will be used for the treatment only of the material that will not bear transportation, such as tails or

concentrates, poor in copper, like Nos. 4 and 5; and the rich mineral and large masses which will bear the expense of transportation will be treated elsewhere. It may be that the time will come when the "mineral" will not be concentrated to such an extent as it now is, and that it will be smelted in a shaft furnace.

Most of the masses come from the Ontonagon district, and arrive at either works by water, and most of the "mineral," as the dressed copper is called, arrives by rail at Hancock or by water at Detroit. The prices of transportation and the questions of freight, which are always interesting, are here matters of prime importance, for the dressing works of the mines are situated in four different ways. Some, like the Osceola, the Allouez, and others, are situated directly on, or a short distance from the Mineral Range Railroad, and have no other transportation. Others, like the Phœnix, have access both by rail or water to the works, being situated far from the railroad and near to the water. Others still, like the Atlantic and the Calumet and Hecla, are on the water but near the furnaces; while all the mines of the Ontonagon district have only water transportation. The Calumet and Hecla is the only one which may have both, as it has its own railroad from Calumet to Torch Lake, and could transport the "mineral" back to Calumet if it chose to do so. The Mineral Range Railroad charges fifty cents a ton for freight; wagon carriage by contracts for large amounts can sometimes be made at about the same price. The Lake freight from the western side of the peninsula to Detroit is from $3.75 to $4 per ton according to the situation of the mine. From Hancock to Detroit it is $3.50 per ton. All the supplies brought to Hancock come as return freight in the great vessels which carry on the transportation between the iron and copper regions and the markets of the East, as these vessels would otherwise return empty. This freight is always at a minimum, and is always the subject of contract. The freightage of the copper is a very simple question in summer when there is plenty of competing water transportation. The copper is generally carried by boat to Chicago, or to Buffalo, and shipped by rail to New York. Only that required for consumption at or near Chicago goes there, the larger part is carried to New York. The cost of this transportation varies from $6 to $8 per ton of 2000 pounds. In the winter there is but one outlet and that is by rail, access to which can be had most directly over the ice to L'Anse, and thence to New York by rail, at a cost of from $24 to $25 per ton. In the winter of 1880–1 about 1000 tons were shipped in this way.

The disposition of the works is such that the vessels arriving with

supplies and those taking off the copper have docks within a few hundred feet of the furnaces where the supplies are wanted and the copper is produced. The docks are supplied with cranes and wagons for rolling the material directly to the place where it is to be used, or for lading it upon the boat. The cranes on the dock lift the masses upon a wagon; and the cranes, either the over-head or the stationary cranes at the refineries, allow of their being charged directly into the furnaces with the least possible manipulation. The doors of the furnace are opened and closed by their own cranes.

The works at Hancock have a large and convenient laboratory, and both works have storehouses for containing the copper, etc. The works count about 290 working days in each year. In 1875 the works at Hancock smelted 36,000,000 pounds, and sent away 14,000 tons of ingot copper, showing a yield of 70 per cent. The capacity of both works is between 28,000 and 30,000 tons a year; of this amount about four-fifths are smelted at Hancock, and the remainder at Detroit. The general yield is between 70 and 80 per cent.

The works of C. G. Hussey & Co. consist of one reverberatory refining furnace, one reverberatory furnace for the treatment of rich slag, and one ordinary cupola furnace for the treatment of the slags from the reverberatory slag furnace. They are situated on the Monongahela River, above the first dam, so that all supplies of coal, etc., are delivered directly at the works. Their position, while very advantageous for coal, requires a maximum transportation for the material to be refined. They treat almost exclusively the ore from the mass mines in the Ontonagon district.

The material treated in the furnaces, if it is in very large pieces, is called a *mass*. If in small pieces not too large to be packed, it is called *barrel work*. These terms originated at the mass mines, where large masses are found which do not admit of packing, and the small pieces which had to be packed in barrels were therefore called *barrel work*. If the material is the result of dressing it is called *mineral*. The barrel work and mineral are delivered at the works packed in barrels. It is usually designated by numbers according to its fineness. No. 1 comprises all the barrel work which does not pass under the stamps, and also the large pieces which are found within the mortar of the stamp mill, and which are too large to pass through the screens; it contains 96 per cent. of copper. No. 2 is about the size of a pea, and contains 92 to 96 per cent. of copper, and 7 per cent. of water. No. 3 is less than half this size, and contains about 90 per cent. copper, and 10 per cent. of water. No. 4 are slimes which contain from 40 to 60 per cent. copper, and from 15 to 20 per cent. of water.

No. 5 are also slimes, coming from the tail house, rarely containing more than 40 per cent., sometimes less, of copper, and 20 per cent. of water. The impurity contained in Nos. 3, 4, and 5 coppers is mostly iron, which comes, for the greater part, from the wear and tear of the machinery used to crush the ore. It is said that some of the ores contain a little specular iron; but it is present in very small amount, if at all. All of these grades are produced in most of the conglomerate and amygdaloid mines.

The mass mines furnish beside the mass copper a considerable quantity of barrel work and very little mineral. The conglomerate mines, on the contrary, furnish comparatively little barrel work, which is usually called No. 1 copper, while the most of their product is mineral, which is so fine that it must be packed in barrels; but the method of packing causes no confusion in the names used for so many years, and now a part of the technical language of the district. Some of the conglomerate mines produce no No. 5 copper, for the reason that their tailings are let out by contract; others do produce it as they work their own tailings. The percentages of copper contained in each one of these grades differs at different mines. As a general thing, the ore charged in the furnaces is calculated to yield from about 70 to 75 per cent. If it were dried, however, it would yield as high as 80 per cent., or even higher.

At most of the mines no assays of the ore are made. The books of the works only, give the results, and there is no attempt made by the miners to check these results by assays, nor is any revision made of them. For the mass mines this would be entirely impossible, but is practicable for the mines which concentrate their product. It is not done, for although there is from time to time a great deal of dissatisfaction felt and expressed with the returns of the smelting works, all the investigations that have been made go to show that fair returns are given for the copper sent. There is a singular practice of weighing the copper in the barrels wet, and then deducting the weight of the barrel, counting all the water as so much copper. A few rude attempts have been made to dry the mineral before packing, but the practice of sending the wet material to the works is almost universal. It was gravely proposed some years ago to take the specific gravity of all the masses, and so calculate the amount of copper they contained,* but it was not carried into practice. The masses are calcined and cooled with water, and the loose rock picked off as clean as possible; they are then weighed as copper. Most of the mines

* Bulletin de la Société de l'Industrie Minérale, 1st series, vol. viii, page 259.

have boys picking over the mineral to separate the silver, but very little of it ever gets to the office, and but little of it is found, so that all the Lake copper contains more or less silver, which injures its quality for certain purposes. As this amounts usually to from twelve to twenty ounces to the ton, a large amount of silver is lost in the course of the year; but the quantity is too small to be separated by metallurgical treatment in this country. Much more might be separated from the mineral by very careful hand-picking, but there is not enough of it to make any very rigid examination worth while, so that most of what is separated in the mines is sold to the specimen dealers, and most of what is separated in the dressing works goes into the pockets of the boys, a very small quantity to the office of the company, and the rest into the copper.

The crucible assay is always used for the copper coming from the mine. The slags from the cupola are dissolved in concentrated sulphuric and nitric acid, two and one-half grams being taken and boiled until the fumes of sulphuric acid disappear. It is then filtered, the iron is precipitated by ammonia, and the copper determined by the color test. When the copper ingots are assayed it is done in a porcelain vessel on platinum strips, a method which is liable to give too high results, as any copper detached from the strips and falling upon the bottom of the capsule is apt to become oxidized. It would be much more accurate to make this assay in a platinum dish.

THE REFINING PROCESS.

The treatment consists of a refining fusion in reverberatory furnaces, producing rich scorias and pure copper, which is cast into cakes if it is to be rolled for the manufacture of sheet copper, into bars if it is to be made into rods or wire, and into ingots if it is to be melted. The crasses and slags are treated either in a cupola furnace, which produces a poor slag and a black copper, as at the Detroit and Lake Superior Works, or are first treated in a reverberatory furnace for black copper, which is smelted with the ore; the rich slags resulting from the reverberatory slag treatment are smelted in a cupola furnace, producing a black copper, which is added to the first black copper produced, and a poor slag, which is thrown away.

The fuel which was originally used to smelt the copper was wood, then charcoal, and now all varieties of bituminous and anthracite coals. Bituminous coals are best adapted to the work, but anthracite can be used to advantage if the furnace is blown at a slight pressure.

The furnaces in which the refining is done are of different sizes in the various works. They are intended to hold from five to ten tons of melted copper. The smaller-sized furnaces are used in Pittsburgh and elsewhere, the larger at Lake Superior and Detroit. All those which treat mass copper have the openings in the roof; those which refine scrap or ingot do not. The principal dimensions are given in the table below.

	Lake Superior. Ten tons.	Pittsburgh. Park Bros. & Co. Ten tons.	Pittsburgh. Park Bros. & Co. Five tons.	Pittsburgh. C. G. Hussey & Co. Five tons.
HEARTH.				
Length of hearth,	14 ft.	12 ft. 10 in.	11 ft. 3 in.	10 ft.
Width at bridge,	4 ft.	6 ft. 9 in.	3 ft. 10 in.	4 ft.
" at charging door	8 ft.	9 ft. 9 in.	7 ft.	7 ft.
Width at working door	2 ft.	Round.	Round.	3 ft.
Inclination	5°	2°	7°	2°.
Depth below bridge at charging door	2 ft. 6 in.	1 ft. 8 in.	1 ft. 10 in.	2 ft. 6 in.
Depth below roof at charging door	4 ft.	2 ft. 3 in.	2 ft. 3 in.	4 ft. 2 in.
Thickness of roof.	9 in.	9 in.	9 in.	9 in.
Size of working door	3 ft. by 1 ft.	1 ft. by 1 ft.	8 in. by 11 in.	2 ft. by 1 ft.
Size of charging door	2 ft. by 1 ft. 6 in.	2 ft. 3 in. by 1 ft. 6 in.	1 ft. 6 in. by 1 ft. 8 in.	2 ft. by 1 ft. 6 in.
Size of movable roof	4 ft. by 4 ft.	None.	None.	5 ft. by 5 ft.
Size of flue	1 ft. by 2 ft.	10 in. by 1 ft. 8 in.	10 in. by 1 ft. 8 in.	1 ft. 6 in. by 1 ft. 6 in.
FIREPLACE.				
Length	3 ft. 6 in.	6 ft. 9 in.	4 ft.	4 ft.
Width	3 ft. 6 in.	4 ft. 9 in.	3 ft. 1½ in.	4 ft.
Depth of grate below roof	4 ft.	2 ft. 6 in.	2 ft. 10 in.	4 ft.
Depth of grate below bridge	2 ft. 6 in.	2 ft. 3 in.	2 ft. 2 in.	2 ft. 10 in.
Charging door	1½ ft. by 1½ ft.	10 in. by 10 in.	11 in. by 11 in.	1 ft. by 1 ft.
Depth of ash-pit	4 ft. 6 in.	4 ft. 3 in.	3 ft. 6 in.	4 ft.
BRIDGE.				
Length next fireplace	4 ft.	6 ft. 9 in.	4 ft.	4 ft.
Length next hearth	4 ft.	6 ft. 9 in.	4 ft.	4 ft.
Width	3 ft.	1 ft. 3 in.	1 ft. 1½ in.	2 ft. 6 in.
Height below roof	1 ft. 6 in.	1 ft. 3 in.	9 in.	1 ft. 8 in.
Height above grates	2 ft. 6 in.	2 ft. 3 in.	2 ft. 2 in.	2 ft. 10 in.
RATIO BETWEEN DIFFERENT PARTS OF THE FURNACES.				
Fireplace	1	1	1	1
Fire-bridge	.91	.26	.36	.625
Hearth	4.5	3.63	5.5	3.25
Flue	.166	.044	.112	.14

Sometimes each furnace has its own stack; sometimes two or more furnaces use the same stack. At the works of Park Brothers & Co., at

Pittsburgh, the stacks are made of sheet iron (Figs. 1 and 4, Plate III), elsewhere they are of brick. In the best constructed furnaces long bars and beams of cast iron are built into the brickwork of the sides of the furnace, both as bearing surfaces for the tie-beams which rest against them, and also to counteract the horizontal thrust which tends to crack the furnace in different places. The furnaces are then tied in the ordinary way, with cast or wrought-iron props held together by bolts. The foundations of the furnace, the outside of it, and the chimney, are built of red brick, and last a very long time.

The ash-pit of all the furnaces is closed with iron doors (Fig. 4, Plate II), and kept closed, except during the latter part of the dipping, when it is necessary to freshen the fire. Air at a slight pressure is forced into it, in nearly all the works. The hearth of the furnace is generally elliptical in shape. At Park Brothers & Co., at Pittsburgh, however, it is rectangular, but rounded at the corners (Fig. 2, Plate III). It is inclined from the bridge towards the working-door, at an angle of from two to eight degrees, rising on both sides so as to make it deepest just under the flue, where a basin, a little larger than the size of the ladle, is made, to facilitate the removal of the last traces of the melted copper. The working door is at the opposite extremity to the fireplace, and just over it the flue rises to enter the chimney. The position of the flue makes it certain that any small quantities of air which enter the working door will pass directly up the chimney and will not oxidize the charge. The flue is generally inclined at an angle of about forty-five degrees and enters the brick chimney which usually stands on one corner of the furnace. As this flue requires to be inspected and repaired quite often, its cover is made of six bricks laid edgewise on iron bearings and clamped and wedged together. They are laid on the flue with the iron clamps on the upper side so that the bricks touch in the cross-section. These composite bricks are then carefully laid up with mortar. At Park Brothers & Co.'s works the flue rises vertically over the working door, and passes into a sheet-iron chimney which rises through the roof of the works.

Between the fire and working doors on the long side of the furnace is the charging door, which is closed and luted when the charge is made. The frames of the door are made of cast iron, filled with brick. They are counterpoised and slide in cast iron frames. The bridge in the Lake Superior furnaces is pierced with eight holes, one and a half by three inches (*d*, Plate II, Figs. 2 and 3); they run nearly across the bridge. They are one brick lengthwise, and are

covered by one brick. These holes slant upwards, at an angle of thirty degrees. The air enters from the ash-pit; its direction is given by an iron plate, which turns the air into the channel, *d*. The quantity to be admitted at any one time is regulated by the lever on the outside of the furnace (*e*, Fig. 4). There is also a flue (*f*, Figs. 2 and 3), which passes on the back of the fireplace over the roof of the furnace, entering it at an angle of about fifty degrees, so as to strike the air coming from the bridge at an acute angle. This valve is controlled by the lever *g* (Fig. 4). These flues, which can be regulated at will, allow of the entry of hot air whenever it is wanted, either to burn the gases or to oxidize the impurities of the copper. These valves once regulated are rarely changed, as the conditions of the fuel and of the furnace are likely to vary but little.

In order to charge large masses, which may weigh from one to ten tons, an opening is made in the roof, shown on Plate II, Fig. 2. This opening is closed with a brick cover, built into an iron frame, and supported from the roof by a chain with large links (Fig. 2 and Fig. 2 *a*). The chain of the cover is attached to an iron wheel, which rolls on an iron beam, supported in the side wall and roof of the building. The frame which holds the brickwork of the furnace cover is three inches wide, and is larger than the opening in the roof. The bricks are built into it so as to fit the frame, and it projects into the furnace about two inches. At Hancock the opening in the roof is four by five feet, which is a little smaller than the size of the bottom of the furnace-cover, which projects two and a half inches on each side over the roof. It is raised by means of chains attached to two iron bars on either side (Fig. 2 *a*), bent so as to receive a cross-bar in the centre, which has a bent bar (*x*), at right angles to the two lower ones, which receives the hook of the chain. On the Lake, in taking off the roof-cover, the hook of the crane on the side of the furnace is attached to the roof-chain and raised about a foot. A hooked link in the chain, made for this purpose, is then raised and attached in the links of the chain above so as to leave the whole roof-cover raised about a foot. The crane is then detached and turned to one side, and the roof is rolled back beyond the furnace, out of the way, and hangs suspended on the bar overhead. At Pittsburgh the furnace-roof is carried by a crane to a hook suspended from the roof behind the furnace and is left hanging there, leaving the crane free to lift the masses. These methods of roof suspension are much more convenient than the arrangement first used, where the cover was raised by the crane and then swung to one side, still attached to the crane, while

a second crane had to be used to manipulate the masses. Now a single crane does the whole of the work; each furnace has thus its own over-head and hand crane. When the furnace is full the roof-cover is rolled back over the opening, raised by the crane, the chain unhooked, and the cover lowered to its place. The length of the chain is such that the weight of the roof-cover does not rest on the furnace, but is borne by the iron bar at all times. The centre of the cover, which projects below the bottom of the iron frame, fits the hole, but the edges project over upon the roof. The lower part of the cover thus projects into the furnace while the sides of it do not, and remain from one and a half to two inches above the roof. The space between the cover and the roof is filled with clay and made tight.

The hearth of the furnace is made by filling in carefully with mortar over the foundations to the depth of about three feet, or better, by throwing a brick arch over the foundations from fifteen to thirty-three inches in height. Over this rich scorias and, on Lake Superior, tails from the washing-machines are placed, making a bed of from six to eight inches thick on the sides. An inverted arch is then sprung over this, which touches the lower arch in the centre. On this the hearth proper is placed, which is made with sand and scrap copper. In order to put in a new hearth the furnace is heated for twenty-four hours to get it sufficiently hot. On the naked hearth two to three feet of sharp washed river-sand is put and thoroughly calcined until all the water is driven off and all the organic matter is burned out of it. It is then brought to the shape required with tools made for the purpose and beaten down with a maul. The doors of the furnace are then closed and luted, and a sharp fire kept up for about twelve hours, the temperature being raised to the highest point of which the furnace is capable. By this time the sand will be glazed; the doors are then taken down and the furnace is allowed to cool for two hours. 1000 to 1200 pounds of scrap copper are then added, which melts and mixes with the sand at a very high temperature, and the furnace is allowed to cool. Whatever copper does not sink into the hearth is ladled out as quickly as possible, and the operation is repeated two or three times until the bed is from ten to fifteen inches thick. When the last addition of copper is melted the hearth is cooled for two hours, and the furnace is then ready for use. The hearth is always made to slope from the bridge towards the working door at an angle of from two to eight degrees. This angle must be such as to make it certain that from all

sides of the furnace the last traces of copper will flow into the dipping-hole from which the copper is ladled. Bituminous coal is generally used in this operation.

I give below the analysis of an old furnace bottom, from Pittsburgh:

Copper,	31 76
Sesquioxide of iron,	3.71
Oxide of manganese,	trace
Lead,	0.16
Lime,	1.05
Magnesia,	0.12
Alumina,	3 83
Silica,	58.91
	99.54

One of the most recently constructed furnaces at Detroit has a water-back on the side of the hearth opposite the working door, or at the back of the furnace. The water for this purpose comes from a large tank beside the furnace, and the hot water, as it runs out, is returned to the tank, the volume of water in the tank being sufficiently large to allow of using the same water over and over again. One course of brick only was laid over the water-back; with this modification the furnaces work well. With Mount Savage brick the furnace at Pittsburgh runs six months without repairs; then the roof and sides give out. On Lake Superior, after a run of about seventy days the roof-bricks wear out and slag off for nearly two-thirds of their length. This wear is caused by the melting off of the bricks on the inside, owing to the high heat and to the fact that considerable ash from the fuel is constantly carried by the flame against the bricks. The drops of melted brick falling into the charge can be seen at any time that the copper is clean, and when the bricks are not of very good quality they fall quite rapidly. The repairs for the eight furnaces at Hancock occupy altogether about two weeks per month. They require for repairs in the course of the year about 150 M brick, which cost $80 at the works. It takes about three months to get a new furnace ready for working.

As soon as a charge has been taken out the hearth must be repaired if necessary; if no repairs are required, which rarely happens, it is charged at once. Usually the sides of the furnace are the most injured. The holes made in them by the material, which has been more or less slagged off, must be filled up, and the hearth, which has become rough, must be beaten smooth. If the holes in the hearth are deep enough to cause the formation of

small puddles of copper there may be danger of their piercing the hearth. These are repaired at once by introducing scrap copper, which cools the melted copper, causing it to become pasty, and thus fill the holes. Small holes or defects in the bottom can be repaired with sand, but large ones must be dried up with metal and then repaired with sand. If the holes in the sides are large, they must be filled with a mixture of powdered fire-brick, and clay well rammed in. The repairs with sand are made with an iron spadelle, with a long iron handle, which is longer than the whole length of the furnace. An iron bar (*v*, Plate II), with an opening in a raised place in the centre, cut out to fit the handle of the spadelle, is placed across the middle of the working door, and the spadelle handle is placed in it. A workman brings quartz sand, which he places on the spadelle, from a pile near the furnace. The long tool is then run into the furnace and the sand thrown on the sides wherever it is needed. When all the back parts of the furnace have been repaired in this way, the tool is withdrawn, and the part near the door is completed with an ordinary shovel. When this is done the slags, very rich in copper, are withdrawn from the bottom of the furnace, cooled with water, and taken away to be put into the furnace in the next charge. The bottom of the hearth is then made smooth by filling up any small holes or irregularities with fine foul slag or sweepings, and the furnace is ready for a new charge. In commencing a new charge the casting basin in the front of the furnace, under the flue, towards which all the copper flows, is filled with charcoal to protect it. This charcoal is at once covered over with mineral or scrap to keep it in position. Generally the whole bottom of the furnace is covered with mineral before another charge is put in.

If the furnace is to be charged with mineral the charge is made at once. When, however, mass copper is to be treated, it must be allowed to cool somewhat, as the hearth is soft, and would be made irregular by the weight of the masses. The heat of the interior of the furnace below and of the cover above is so great that the workmen could not endure it, for one man, and sometimes two or three are obliged to stand on the top and to work through the open roof, receiving all the heat radiated from the hearth and the interior of the furnace, and although they are assisted by men below working through the doors at the side to direct the movement of the copper to the proper place in the furnace, the work is both difficult and painful. It requires a great deal of judgment to place the masses, as they are large, heavy, and very irregular in shape. If they

were not carefully packed the furnace would be full and still leave a large number of interstices. Before charging these masses, mineral is usually placed in the furnace and evenly spread out over the hearth to the depth of several inches, and if the masses are very large, pieces of wood are placed on the mineral to prevent damage to the hearth, as well as to have a space to draw out the chains by which they are lowered into the furnace. As the masses are often longer than the opening in the roof, they have to be swung in such a way that they can be tipped down at one end through the roof and then slid into the furnace. The large sticks of wood upon which the copper rests are withdrawn as soon as each mass is in its proper place. The very large pieces are stowed away first, and after these the smaller ones. Then mineral is thrown in with shovels wherever it will go until the full amount of the charge is in the furnace. When all the charge is in the cover is brought back over the opening. It is lifted by the crane until the hook can be taken out; it is then lowered to its place. The weight of the roof-cover remains suspended on the beam above. It would not do to leave the heavy mass of the roof-cover on the roof without any support, as it would be liable to crush in the roof, since it has a very flat arch (Fig. 3. Plate III). Once in position it is carefully luted with clay, and any portion of the charge that does not require to be put through the roof is then put in through the working door. It takes four men one and a half hours to fill the furnace. When mineral alone is charged the roof does not require to be raised, and the charge is more rapidly made. All the mineral from the Keweenaw mines arrives at the works in barrels, which are petroleum casks, 20 inches in diameter, and 3 feet 6 inches high, and are always saved. They are recoopered by the furnace company at the expense of the mine, and are returned, unless they are so badly damaged as not to justify the expense. In order to do the least damage to them they are caught by chine hooks, and raised by a crane two or three feet from the ground. The heads are carefully removed so as to damage the barrel as little as possible; the contents fall on the floor in front of the charging door, and the barrels are sent at once to the cooper shop. At Pittsburgh no care is taken of the barrels; they are broken open with axes as they lie on the ground, and the wood burned to smoke the moulds; but it takes three times as long to discharge them as by the method used at Lake Superior.

The furnaces on the Lake are charged at about 1 P.M. The charge is composed of ore, rich slags, and limestone, which is used

as a flux, and has been crushed fine in a Blake's crusher. Two wheelbarrows of it are charged at a time. It is mixed with the mineral as it lies in front of the charging door of the furnace before charging, and is thrown into the furnace with it. It constitutes 6 to 8 per cent of the charge. From six to eight wheelbarrows of rich slag, which will weigh about 1500 pounds, are thrown in last. These slags often contain as high as 25 to 30 per cent. of metallic copper. The charge is arranged to contain between eight and nine tons of ore, which will yield by assay, from 80 to 85 per cent. of copper. It takes six men about an hour to make a charge of mineral. The number of men required to charge the masses, and the time required to do it is very variable, depending on the difficulty of introducing them into the furnace.

The following is the analysis of a slag used in the charge at Pittsburgh:

MECHANICAL ANALYSIS.

Metallic copper,	8.2
Siftings,	91.8
	100.00

ANALYSIS OF THE SIFTINGS.

Protoxide of iron,	7.71
Copper,	18.78
Oxygen with copper,	4.74
Oxide of zinc,	0.26
Oxide of nickel,	0.84
Oxide of manganese,	0.07
Alumina,	13.48
Lime,	10.25
Magnesia,	2.10
Silica,	41.07
	98.80

The fuel used on Lake Superior is a lean bituminous coal with a long flame, which is brought from Ohio. At Pittsburgh, the bituminous coals of that district are used. In the East a mixture of bituminous and anthracite coals is used, and to some extent, anthracite alone. From 3½ to 4 tons are consumed, in twenty-four hours, in each furnace. It costs on the Lake from $6.00 to $6.50 per ton, delivered.

At Pittsburgh the furnace, which is much smaller than that on Lake Superior, is started at 1 P.M., with from four to five men. The charge introduced in the furnace is 14,000 pounds. The ore used is mass and barrel work, and three grades of stamp, one coarse, and

the others very fine. When mass copper is used, it takes three hours to make the charge. The fireplace is then filled with fuel and all the doors luted. Two men are kept at the furnace during the night shift, which commences at 6 P.M., to keep the fire and look after the charge in the morning. At the end of an hour after the ordinary charge of stamp ore, the fire is increased so as to bring the heat of the furnace up to a bright red, and the doors are luted. The furnace is kept at this heat for the rest of the day.

When the operation of charging has been performed, the workmen engaged about the furnace check the weight of the barrels containing the ingot copper, made during the morning; they are then coopered by the coopers of the works and rolled to the wharf ready for shipment. When the work is done before the end of the shift the men go home, except one man, who watches the furnace until the night shift comes on at 6 P.M. The operation is divided into three parts: fusion, fining, and refining. The charging and fusion last about twelve hours, the removal of the slag four to five more. The fining takes from one and a half to two hours, the refining about two hours, and the casting two hours. The furnace will thus be about twenty-two hours in operation. The repairs to the hearth and to the rest of the furnace take about two hours, so that only one charge can be smelted in twenty-four hours. It is not always economical to make very large charges in a furnace, for while most of the furnaces would undoubtedly contain more, the difficulty of keeping in the copper is much greater with a large charge, and when the furnace bursts from too great a pressure of melted copper, it is difficult to repair the damage rapidly enough to prevent loss. If the break is small, water may be played upon the stream of copper and against the furnace to make it solidify, and sand packed on the inside where the break occurs. If the break is large, water could not be used, as it would cause explosions and projections of the metal, making it dangerous to go near the break. In such a case plates of copper and slag must be put against the break on the inside of the furnace to chill the metal in the crack, and sand packed in it on the outside. The furnace should always be brought to its heat gradually, so that the whole charge will be at an even heat at the same time, and all will be ready to melt together. If this is not done, and the temperature of the furnace is increased too rapidly, the upper part of the charge will melt and cover the rest, which will then be very difficult to melt, and will cause more fuel to be used. To produce the even tem-

perature necessary to make the charge melt uniformly, the doors of the furnaces are closed and luted as soon as the charge is introduced, and the furnace slowly heated for about six hours. Two men take charge of each furnace, who keep up the temperature, and take off the slag during the night; they make four to five skimmings of slag. The fireplace is charged every hour. The damper at the top of the chimney is kept open during the whole operation, except near the close of it, during the refining, when it is necessary to keep the temperature exactly the same. The first slags are drawn at about 9 P.M., and every one and a half to two hours afterward. This work is done by the night men who come on at 6 P.M. They draw off the slags with a rabble, through the working door, which takes about ten minutes each time. This rabble is made of iron; it is four inches high, six and a half inches wide, and has a handle twenty feet long. It is run into the furnace door over a skimming bar, which fits into sockets (*u*, Fig. 1, and 3, Plate II) cast or bored in the iron plates. Whenever the crasses, which are very thick and pasty, are drawn, a plate of sheet iron is put up between the workmen and the furnace door. This shield rises to the level of the working door, and the men are protected from the heat of the crasses, which are red hot. As soon as they are out, the handle of the rabble, which is red hot, is straightened, and the bath covered with charcoal.

On Lake Superior the slags fall upon the floor of the works, and are cooled with water in order to render them sufficiently brittle to break up easily. The small pieces are taken away as soon as they are solid, in wrought-iron wheelbarrows, the large in slag barrows (Fig. 13, Plate II), made for the purpose, and are either carried directly to the cupolas, or are put into the slag bins to await their turn for treatment. At Pittsburgh the slags are drawn into a sand bed in front of the furnace, and when cool taken outside the works to undergo a subsequent treatment in a reverberatory furnace previous to the cupola treatment.

The casting-bed is made in three parts, and the bed so made is called a "pair." If only two parts were made in the bed, the cakes would be too heavy, and if four, too light; besides this, there is only room in front of the furnace for three. At 11 P.M., another skimming is made as before; the door is now again luted. Four to six skimmings are made in this way. They do not always take exactly the same time, sometimes more, and sometimes less. After every skimming the workman feels the furnace by running the rabble over

it, and when, on going over the bottom, he finds everything is melted, the skimming is suspended.

I have given below a number of analyses, made since 1869, of these slags, as I have been able to procure them. They are taken as examples of refining from both native and sulphurous ores. I was not allowed either to take or obtain a recent sample of slag from Lake Superior. The three analyses of Lake slags were made in 1869, as a matter of metallurgical interest. All the other analyses have been made expressly for this paper.

What was, and what was not soluble was first ascertained. The analyses of each of these was then made, and subsequently the analysis of the slag as a whole.

	Albany and Boston.	Pewabic.	Isle Royal.
Soluble	27.87	14.40	17.59
Insoluble	72.13	85.60	82.41
	100.00	100.00	100.00
SOLUBLE PART.			
Copper	29.14	61.27	17.59
Iron	70.86	38.73	82.41
	100.00	100.00	100.00
INSOLUBLE PART.			
Protoxide of iron	15.63	18.47	10.61
Suboxide of copper	.....	5.14	1.80
Lime	10.75	10.90	4.11
Alumina	8.94	15.88	11.36
Magnesia	8.18	2.67	1.80
Silica	56.48	45.55	70.43
	99.98	98.61	100.11

When these slags are analyzed as a whole, they contain:

	Albany and Boston.	Pewabic.	Isle Royal.
Metallic iron	19.69	5.57	16.34
Protoxide of iron	11.18	15.86	8.74
Copper	8.09	13.12	2.73
Alumina	6.40	13.59	9.36
Lime	7.69	9.33	3.39
Magnesia	5.85	2.28	0.76
Silica	40.39	38.99	56.05
	99.29	98.74	99.37

The average of these three samples is 7.98 per cent. of copper, which is much lower than they will usually average.

The following determinations of copper and iron were made of the slags from Pittsburgh:

	1	2	3	4	5	6	7	8	9	10	11
Copper	14.07	10.55	11.38	10.39	8.59	7.71	7.41	6.44	6.16	6.11	5.85
Iron	12.33	15.11	15.61	13.49	12.38	15.76	17.99	15.61	12.23	12.33	13.36

	12	13	14	15	16	17	18	19	20	21	22
Copper	5.26	5.08	4.94	4.48	4.14	3.63	1.52	0.93	0.91	0.63	0.56
Iron	14.63	14.63	20.24	18.01	15.76	16.89	14.47	13.36	16.89	12.69	14.47

It will thus be seen that the percentage of copper is very variable: one has between 14 and 15 per cent.; two have between 11 and 12 per cent.; one has between 10 and 11 per cent.; one has between 8 and 9 per cent.; two have between 7 and 8 per cent.; three have between 6 and 7 per cent.; three have between 5 and 6 per cent.; three have between 4 and 5 per cent.; one has between 3 and 4 per cent.; one has between 1 and 2 per cent.; four have between 0.5 and 1 per cent. These slags are quite rich, there being only six out of the twenty-two below 4 per cent. This makes an average of 5.67 per cent. of copper. There is but little variation in the iron, it being from 12 to 20 per cent.

The following are the analyses of slags treated in the reverberatory furnace at Pittsburgh. They were taken from the furnace at intervals. They, like all the refining slags, are composed of a friable part, which was sifted out and the metallic copper determined.

MECHANICAL ANALYSES.

	1	2	3	4	5
Metallic copper	3.40	0.00	3.37	0.51	0.00
Siftings	96.60	100.00	96.63	99.49	100.00
	100.00	100.00	100.00	100.00	100.00

ANALYSES OF THE SIFTINGS.

	1	2	3	4	5
Protoxide of iron	12.46	11.43	12.01	12.02	10.53
Copper	4.82	4.53	5.05	5.80	5.44
Oxygen with copper	1.22	1.24	1.28	1.46	1.37
Oxide of zinc	0.37	0.56	1.52	0.75	0.43
Oxide of nickel	0.06	.....	0.47	0.18	0.08
Oxide of manganese	0.05	0.04	0.15	0.13	0.12
Alumina	15.71	14.52	15.21	14.48	15.36
Lime	14.34	14.75	14.79	15.25	11.81
Magnesia	4.07	3.99	4.11	3.90	2.57
Silica	45.32	46.94	45.81	44.66	49.83
	98.42	98.40	100.40	98.63	97.54

The following are analyses of refining slags, resulting from the treatment of sulphurous ores at Ore Knob:

MECHANICAL ANALYSES.

	No. 1.	No. 2.	No. 3.	No. 4.
Metallic copper	40.5	26.9	48.5	30.0
Siftings	59.5	73.1	51.5	70.0

ANALYSES OF THE SIFTINGS.

Oxide of copper	25.50	17.48	47.43	45.34
Oxide of iron	44.54	42.24	17.33	15.53
Sulphur	4.66	1.87	0.44	0 16
Alumina	1.11	1.69	0.64	0.90
Oxide of manganese	0.10	0.22	0.08	0.08
Lime	1.97	3.70	2.63	2.89
Magnesia	trace	0.71	0.33	0.44
Oxide of cobalt	0.71	1.74	7.53	1.56
Oxide of nickel	0.27	1.87	10.41	2.90
Oxide of zinc	0.60	0.85	0.00	0.20
Silica	21.38	27.89	13.47	28.48
	100.84	100.26	100.29	98.[illegible]

ANALYSES OF THE REFINING SLAGS AS A WHOLE.

	No. 1. Six hours after charging.	No. 2. 7 P.M.	No. 3. 2 A.M. Boiling ceased.	No. 4. After first poling.
Metallic copper	40.50	26.90	48.50	30.00
Oxide of copper	15.19	12.79	24.45	31.77
Protoxide of iron	26.50	30.88	8.91	10.87
Sulphur	2.77	1.37	0.23	0.11
Alumina	0.66	1.23	0.33	0.63
Oxide of manganese	0.06	0.16	0.04	0.06
Lime	1.17	2.70	1.35	2.02
Magnesia	trace	0.52	0.17	0.31
Oxide of cobalt	0.42	1.27	3.88	1.09
Oxide of nickel	0.16	1.37	5.36	2.03
Oxide of zinc	0.36	0.62	0.00	0.14
Silica	12.72	20.39	6.94	19.94
	100.51	100.20	100.16	98.97
Total metallic copper contained	54.0	38.26	70.0	58.21

The metallic copper is in grains; the oxide of copper is mostly combined with silica, and partly free as oxide. These Ore Kn[illegible] analyses are remarkable as showing a concentration of cobalt and nickel at certain stages. The total amount of slags removed from a five-ton charge will be between 1500 and 1000 pounds, and in about the same proportion for larger ones.

The large pieces of mass-copper charged upon the hearth rise up to the arch, and consequently during their slow fusion go through an oxidizing action. When the whole charge is fused it is allowed to remain in complete fusion for two hours in order to give to the scorias sufficient fluidity for the grains of copper to separate. This condition is maintained until the slags no longer rise. The copper is then ready for fining.

If a sample of copper is drawn from the furnace at this time, the surface of the test will be rounded and very uneven. The surface will have the appearance of a rosette with a more or less vermicular

appearance between the centre and the rim. The amount of oxygen contained in a sample taken for the purpose was found to be 0.72 per cent. Most of the slag which is skimmed in the night is sent to the cupolas. The little that contains grains of copper goes back into the furnace at the next charge.

The air which enters the furnace makes oxides of the base metals, and produces a certain amount of oxide of copper at the same time. This action of oxidation is not, however, energetic enough to take out all the impurities. The oxides of the foreign metals, as they form, combine with the silica of the charge, or take it from the sides of the furnace to form a slag, which is very pasty at first, as there is often too little silica. The fusion will not be complete before from one to two o'clock A.M., so that there will be several removals of slag during that time. The scorias which form will be rich in copper, some of them containing 30 to 40 per cent. On the average they contain about 12 per cent.; of this amount from 3 to 6 per cent. will be oxide, and from 3 to 8 per cent. copper in grains. The fusion and oxidation is greatly facilitated on the Lake by the openings in the roof and bridge which allow of the introduction of just enough hot air, which has not passed through the fireplace, to effect the separation of the impurities as oxides.

The test taken now shows the copper convex in the middle, with sproutings of copper on the top, so as to give it the appearance of a rosette. It has an irregularly granular fracture, and contains from 0.44 to 0.77 per cent. of oxygen.

Rabbling is commenced usually about six A.M., earlier if the furnace is ready, or later if it is not. Up to this time the furnace has been in charge of the two night firemen. On Lake Superior six and at Pittsburgh four melters now come to the work, two of whom work at the casting, and two at the side door. The two men in front are called the furnace men, and the two others the helpers. These men alternate with each other in their work on alternate days, the furnace men becoming helpers and the helpers becoming furnace men. The furnace men always have charge of the furnace. They rabble from one to one and a half hours, or until by a test the metal takes a set, or is deep red and very coarse in grain. In rabbling care must be taken not to plunge the rabble deep into the copper. If this is done the copper gets over the head of the rabble, and it is very difficult to clean it off afterwards. It must be pushed over the surface so as to make the copper splash, but not splash high. The

men work alternately, and the work must be constant, and is very severe while it lasts.

The action during the operation of rabbling is one of oxidation. To insure it the fire on the grate is allowed to fall, and the coal is picked, the larger pieces being used, so that unconsumed air may pass into the laboratory of the furnace through the interstices of the coal. Air is also allowed to enter over the fuel in the fireplace door. In the furnaces which do not have the slide-valve, openings are often made in the sides of the furnace to insure the necessary supply of air. The action of oxidation should, however, not be carried beyond the certainty of having a small amount of suboxide of copper dissolved in the bath. The charge when ready is never allowed to lie over, and the day-men are notified to be on hand when the charge is ready, and they remove the last slag.

Shortly after the rabbling commences, tests for a set, or to ascertain the quantity of suboxide of copper dissolved in it, are taken frequently. The object is to make the copper as dry as possible, by causing the suboxide to form and dissolve in the copper. The test for a set is taken behind the rabble; it is cooled with water and hammered on an anvil to flatten it, nicked with a chisel, and broken with a hammer in a vise. The first one usually shows shiny grains, the next has a fine grain running at right angles to the surface, the third has a mottled appearance. As soon as this is shown, brand and charcoal are thrown in and the heat is brought up to commence poling. All of the test pieces taken up to this time show a bubble-hole in the centre when broken through the middle. The test is taken in an assay ladle made of half-inch iron 5 feet long, with a knob for a handle 1 inch in diameter at the end. The ladle is forged out of the other end, and is $1\frac{1}{4}$ inches in diameter and $\frac{1}{2}$ an inch deep, rounded on the bottom. If the test is taken before the metal has taken a set, the metal will blow, bubbles rising and forming a worm, running all over the surface, in which case it needs more rabbling. If the set has taken place, the test is concave, which shows the absorption of suboxide of copper, and that the metal is now dry, and both cold-short and red-short. These samples are always broken in two. If there are streaks of light and dark in the broken metal, the rabbling is commenced again and continued until the broken test piece is all of the same color.

Whatever slag accumulates during the intervals of rabbling is carefully removed, but if it has been properly crassed before, there

will be but little, probably not more than from 50 to 250 pounds. Samples taken at different times during the rabbling, and just before poling, gave the following results:

	OXYGEN.							
	1	2	3	4	5	6	7	8
Immediately after melting	0.73			0.44				
Starting to rabble	0.99						0.45	
After rabbling half hour	0.92		0.85					
After rabbling one hour	0.91	0.77				1.38		
After rabbling one and a half hours	1.02					1.44		
After rabbling two hours	1.03		0.90			1.52		1.8
Before commencing to pole	0.93	0.37	0.97		0.77		0.85	0.75

In the intervals of rabbling, and from this time to the end of the operation, the cast-iron door of the furnace is not used; when it is necessary to raise the temperature, or to change the quality of the flame, a piece of refuse sheet copper or of sheet iron, bent at right angles at the top so as to be readily lifted off with a shovel and put to one side, is used.

The copper now contains a very considerable amount of suboxide of copper dissolved in it, which must be separated before the metal can have any commercial value. If the operation has been properly conducted, the copper is very dry, and is both cold and red short.

The operation of poling, which is the commencement of the operation of refining, now begins. Its object is to reduce the oxide of copper, or, as the refiners say, toughen the metal, or work for a tough pitch, which is done rapidly, because the only foreign material is oxide of copper, which is easily reduced by the carbon. It does not take more than one to one and a half hours, during which time frequent tests must be taken. All the slags which are taken off, during either rabbling or poling, are put back into the furnace with the next charge. It will now be about eight o'clock, or two hours since the rabbling was commenced. The surface of the metal is carefully cleaned and covered with cord-wood and charcoal; the doors of the furnace are put up and luted for half an hour or more to get up the heat and make it as little oxidizing as possible. The surface of the metal is then again cleaned and covered with from two to four bushels of charcoal and some cord-wood, so that the whole face of the metal is covered with them floating on the surface. The pole is now introduced. For this purpose hard wood is generally selected, usually beech, but this is not essential, though it seems to be the best. Most refineries are not very particular, and take what wood they can get, which is of the proper size, rejecting, of course, the very light woods, which would burn too quickly. The pole is from 6 to 10 inches in diameter, and from 15 to 25 feet long. The greener the pole the better. It would be well to keep all these poles in water to

insure a sufficient quantity of steam to make the metal boil. In some works the pole is supported in its position in the furnace against the top of the working door above by a crutch, called "a horse," made by cutting a notch out of a board, and is taken down by removing the horse and withdrawing it from the furnace. Such a disposition of the pole wears away the arch of the charging door. In some of the furnaces the pole is for this reason made to rest against an iron bar (*r*, Plate 2), placed in the holes (*u*, Figs. 1 and 3) made in the supports in the side of the working door, so bent that the pole is near the top of the door without touching it. The crutch is best made of inch square iron, 3 feet 6 inches long, on the bottom of which there is a notch 11 inches wide and 7½ inches deep, and on the top one 9 inches wide and 4½ inches deep, which is a much more permanent and a better way of supporting the pole. Before the pole is put in a test must be taken. The poling is usually commenced as soon as the heat is sufficiently high to be sure that every part of the furnace is equally hot and the charge of an even temperature. Tests must be taken every ten to fifteen minutes during the whole period of poling, until there are no black specks shown on the surface of the fracture near the centre, and until the assay sample shows a fibrous texture and silky lustre. The grain of the copper during the operation keeps growing finer and finer until no grain is seen, and it is then silky. Every time the test is taken, the pole is taken down. The reason for this is that a fair test cannot be got when the metal is boiling. Whether the pole is to be put up at once, or the surface skimmed and more charcoal introduced, depends upon whether there is any slag on the metal. If there is any it must be removed before the pole is put up, and about the same quantity of charcoal as before added. The pole may be put up four or five times, sometimes six, and sometimes three, depending upon how the copper comes to nature. The ebullition from the pole is so violent that considerable material accumulates around the working door, which is cut off with a long bar when the pole is taken down. In some works, when the grain is very open, about 1 to 1½ pounds of lead to the ton of copper is added. If the copper is very difficult to refine, the lead is added about the middle or near the close of the operation. The object of the addition of the lead is to make an easily fusible compound, which will tend to bring the oxides and other impurities to the surface. It is usually added when the copper is to be worked into sheet metal, but must never be used when fine copper for any other purpose is to be made. This introduction of lead into the

copper is a very bad practice. It makes it easy for the refiner to work his charge, and makes the copper roll easily, and most refiners are of the opinion that all of the lead, which oxidizes so easily, is carried off in the crasses, but this is not so. A part of it is undoubtedly oxidized, but some of it still remains, as the analyses always show when it has been used. It makes the copper of such inferior quality that it cannot be used for certain purposes. It is a matter of habit with most refiners, and should be peremptorily forbidden, when the quality of the copper is expected to be high. Some refiners use lime to slag out the oxide. The lead is introduced on a small spatula which is passed over the surface of the copper, moving it from side to side, and backwards and forwards over the charge, so as to melt all the lead and distribute it over the surface. Not more than one pound for the ton is introduced when copper shows brittle. If the lead were all introduced at one time in a single lump it would sink to the bottom, and might corrode it, and would not be evenly distributed through the charge. If it should all go in one lump it would make a hole in the bottom of the hearth. As soon as the lead is all melted, it being scattered over the surface of the charge, the pole is put up. If the copper is of good quality to commence with, it does not need the lead, although it will roll a little easier with, than without it. I have seen it, however, added to the best Lake copper to satisfy a prejudice of the mill men, but many mills work without lead. The quantity added is very variable, and when the copper is cast into ingots it does not appear to affect the grain, but it always deteriorates the copper when it is to be used for any other purpose than rolling.

A series of tests made just before and after the introduction of the lead gave the following results:

	Oxygen.
Just before putting in the lead,	0.53–0 55
When the lead was added,	0 55
After ten minutes poling,	0.56
After five minutes more poling,	0.44–0.46
After three minutes more poling,	0 29

Another set of samples where no lead was introduced is very interesting, as showing in the one case an increase, and in the other a decrease, of oxygen during the operation of casting, and as showing the fluctuations of the iron.

FIRST SET.

	After 1st pole.	After 2d pole.	After 3d pole.	Near the end of refining.	¾ hour after ladling.
Oxygen.....	0.42	0.85	0.47	0.81	0.085
Iron.....	0.036	0.057	0.06	0.11	0.065

SECOND SET.

	After rabbling.	Before poling.	After poling.	1 hour after ladling.	1½ hours after ladling.	End of ladling.
Oxygen.....	1.014	0.75	0.214	0.405	0.425	0.423
Iron.....	0.036	0.09	0.08	0.075	0.075	0.065

Another series of samples taken at various times on different charges and at intervals of many months, with a view to ascertain exactly what the reactions in the furnaces were, gave the following results:

	OXYGEN.						
	1	2	3	4	5	6	7
After poling half hour, ...	0.19	0 25	0.55	0 37	0.44		0.19
After poling three-quarters hour, .	0.14		0.56	0.25	0 48		0.12
After poling one hour, ...	0.12		0.44		0.48		

These samples show a very great variation in the quantities of oxygen and consequent purity of the copper. No importance is attached to it, however, and these small amounts are generally too small to influence the color.

The action during the whole period of poling is one of reduction. This must be insured by charging the fireplace to its maximum, and by closing as tight as possible every aperture through which any unconsumed air could enter the furnace, and by keeping the bath covered so as to provide a substance for the oxygen to attack in case any is present. Notwithstanding all these precautions, some oxygen does attack the copper. The reduction of the last portion of the oxide should be done slowly and by the carbon alone, in order that the workmen may have time to get the exact point for casting when all the oxide of copper is reduced. The charcoal is then left upon the surface of the copper to counterbalance the oxidizing influences.

When the metal is over-poled the copper is brittle, and has a shiny yellow color and a very brilliant lustre, and reflects distinctly every detail of the interior of the furnace. The whole operation has then to be gone over again from the first rabbling. Over-poled copper, or copper containing carbon, is not entirely free from oxygen, as is generally supposed. An analysis of a sample showed 0.119 of oxygen. If much carbon or oxygen is present, carbonic oxide is formed, and a porous condition of the copper results, which makes it entirely unfit for ordinary commercial uses. The usual test for tough pitch is that of not rising on the surface. This might not be satisfactory, as it depends upon the thickness of the cake or test-piece; the surface of a thin one may not rise when a thick one would. When depressed on the surface the copper is underpoled.

The less oxygen the copper contains the flatter its surface will be, so that this may be almost said to be a good rule by which to judge of the quality; but while a level surface is a good indication of itself, it cannot alone be taken as an indication of a high grade of copper. While there is any oxide of copper the grain of the metal is large and the color is red. Just as soon as the texture becomes fine and the metal perfectly malleable, with a silky lustre, the casting should be commenced. In order to make the last test, a mould (Fig. 15, Plate II) is used at Pittsburgh, which gives a button two inches in diameter and two inches thick, with a small handle four inches long attached to it. The object of the handle is to catch the test button with the pincers while the circular part is beaten out as thin as possible on an anvil. If the copper shows any cracks on the thin edges the poling must be continued until no break of any kind is shown, no matter how thin it is beaten.

At Lake Superior the test was formerly made by blows, but it is now made by transverse strain, an ingot about two inches wide by eight or nine inches long being cast for the purpose. It is supported upon the two ends and pressed upon until it breaks by a screw run by a steam-engine, the ingot being first nicked. The quality of the copper is judged by the color of the fracture. The former test on the Lake was fourteen blows of a fifteen-pound sledge on the ingot, which often bears eighteen, nineteen, or twenty blows. In making the tests the assay pieces are nicked with a chisel, and bent backward and forward in a vise by striking with a hammer. The copper is said to be tough pitch when it requires frequent bendings to break it, and when, after it is broken, the color is pale red, the fracture has a silky lustre, and is fibrous like a tuft of silk. In such a condition the copper is apt to rise in the moulds, but can very easily be regulated so as to have a flat surface, which is important to the rollers, and the reason why so many add lead is both to prevent this rising and to make it roll easier. After the pole is taken down the accumulations of slag around the door are cut off with a bar, and the sheet door is put up to get the temperature up to the proper point for casting. When the assay shows that the furnace is ready, ladling is begun, and a test is made from time to time, during the casting, by either taking an assay, or by breaking some of the ingots, as at Detroit, exactly as it was done with the small test-pieces. During the time of casting it is necessary that the gas in the furnace should be kept neutral, or that there should be an equally balanced oscillation between an oxidizing and reducing action, so that the copper

shall neither be under-poled nor over-refined. The casting door, remaining open during all the time of the casting, furnishes some oxygen, but not too much if the fireplace is in proper condition, as the air goes directly up the chimney. During the whole time of casting the face of the copper must, for this reason, be kept covered with charcoal, and sticks of cord-wood kept burning on the surface of the charge so as to make the atmosphere reducing. The charcoal is shoved away when the ladles are introduced. It rarely happens, however, that the furnace is kept in exactly the same condition during the whole time of casting, as the analyses given below show, so that frequent tests must be made to see when the pitch changes, and occasionally the operation of casting is stopped and the furnace closed to bring the heat up and the pitch back to its proper condition. A well-regulated furnace ought to have the temperature as well as the quality of the heat such that no stopping will be necessary during the casting. It is, however, an exception to have the furnace work continuously without stopping. The following determinations of oxygen were made in the same series and on the same charges as those given under poling. A greater variation is very often shown, but these are about the average of good working.

	OXYGEN.						
	1	2	3	4	5	6	7
Ready for ladling,	0.10	0.24	0.29	0.24	0.60	0.22	0.1[illegible]
Ladling half done,	0.12				0.19	0.41	0.1[illegible]
Last of the charge,	0.10	0.30		0.30		0.43	0.1[illegible]

Sometimes the furnace is too cold. Other things being equal, this does not affect the quality of the copper, but it makes the ingots dirty-looking, and increases the difficulty of the work.

The bath is composed of metallic copper and oxide of copper. It is very easy to distinguish the bed of oxide of copper which forms, because it continually breaks and exposes the melted metallic copper, which, in its turn, is rapidly oxidized. The casters shove this bed off from the surface before they dip the copper out; but even then there is almost always a thin coat of it floating on the ladles, especially if the ladle is exposed for a few minutes to the air. If the copper is in proper condition two men with ladles (Fig. 7, Plate II), nine inches in diameter and five inches deep, dip out the copper. The ladles are first washed with a thin mixture of kaolin and water. They are dried on the top of the furnace, and are then heated to nearly the temperature of the copper, so that it will not chill, by introducing them through the working door and holding

them just over the copper. After they have been used for about an hour they become red-hot and are then put into the water trough to cool, and are re-washed and used again. The ladles vary somewhat in size, and hold from thirty to forty-five pounds of copper.

The copper is cast into different shapes, according to the uses to which it is to be put. If it is to be made into rods or wire it is cast in rectangular iron moulds, which have been previously washed with wood ashes, and dusted with fine charcoal from a bag, or have been smoked with wood, usually old barrel staves, to prevent the adherence of the copper to them. These moulds are set about a foot from the floor and are exactly level, so that they may be poured full. They are from 25 to 40 inches long, and from 3 to 7 inches square. They are made to taper for about 6 inches from one end to about 2 inches square on the bottom and sides, the top remaining flat, so that they can be made to enter the rolls easily. As soon as they are cool they are tipped over upon the floor, the end of the mould is lifted with an iron hook, and the billet falls out. They are always made of the size required for the number of ladles they are to contain, and generally weigh from 80 to 100 pounds.

When the copper is to be rolled into sheets, it is cast into cakes, which are of any size or thickness required. The small cakes or plate-moulds are usually square, the larger ones rectangular or round. They are generally from 18 to 32 inches square, and 10 to 15 inches deep. The smaller ones are usually 14½ by 18½ inches, and about 12 inches deep. In such a mould five cakes about 2 inches thick will usually be made. A cake 2 feet square and 4 inches thick will require fifteen ladles of 40 pounds each. Round cakes 3 feet in diameter and 10 inches thick are sometimes made, which will weigh as high as 2500 pounds. The largest square casting-moulds are 3½ feet square, 10 inches deep, 1½ inches thick on the sides, and 3 inches on the bottom. A cake 6 inches thick made at Pittsburgh, by C. G. Hussey & Co., from such a mould weighed 3135 pounds. The moulds for casting the cakes are made either of cast iron or copper—usually the former. They are generally cast in two pieces, divided through the diagonal. Before being used the cracks are filled with sand, and the bottom and sides coated with wood ashes. They are sometimes, as at Pittsburgh, for small cakes, cast full and not in sections, and have ears cast on one side, through which a pin is put to manipulate them. These are easily moved and do not require the clamps, but they frequently break.

The first ladle is poured so as to form a thin film over the bottom,

and when this has become cool the regular casting commences. This first thin sheet is always sent to the scrap, and is called the waste cake. As the bottom cake cools a thin film of oxide of copper forms on the surface, which is of sufficient thickness to prevent the adherence of the next cake, which is poured directly on it. The thickness of the cake depends on the number of ladles, which give approximately the weight of the cake. In order to make the cake of even quality each ladle has to be poured quietly in the direction of each side of the mould and in the middle. There is the greatest possible difference in the skill of the men who do this work; some will spill and splash the copper, and throw it in small drops, others will pour it quietly and evenly. Every heavy splash can be seen on the side of the plate or ingot after it is cool, and detracts much from its looks. As it is not possible to tell how far a crack seen on the surface penetrates into the metal, it may even make it of little value, if the splash has been made when the copper is near the point of solidification. When very large cakes are to be made, a considerable quantity of copper is accumulated in a large ladle moved by a crane, which is carried to the mould. Four or five men then stand ready with their ladles, so that the copper from the large and small ladles is turned into the mould at once. If this were not done the copper on the bottom would chill; but when a sufficient quantity has been accumulated at first the men can easily keep the heat up by pouring quickly. Only one plate is made over the waste cake in a large mould. When all the cake moulds are full, they are left until they are sufficiently cold to bear moving; the clamps and wedges which hold the two parts of the mould together are then removed by striking them with a bar. They are placed together near the moulds so as to be used again. One man, with a bar bent at the end, pries under one side of the mould at the point of separation, so as to move it a little to one side. Two men with straight bars introduce them between the cake and the mould, and move it away from the cake. While this is being done, the man with the bent bar pulls the cake away from the other half of the mould, after which the two men with straight bars throw the cakes upon the floor, and turn them on their side so as to separate the cakes with wedges. As soon as the moulds are sufficiently cool they are reclamped and set in place. It seems a simple thing to make these large castings, but in reality it is very difficult, for if the copper is not properly refined, ridges from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch deep form on the surface which it is impossible to roll out. I have seen suboxide of copper $\frac{1}{16}$ of an inch thick on

such cakes, and have known of cakes weighing 3000 pounds which had to be returned to the furnace for this reason.

When the copper is to be used for melting it is cast into ingots (Fig. 12, Plate II), in copper moulds. A very large proportion of it is cast in this way. The ladles should contain copper enough to fill two ingot-moulds, but actually a ladle generally makes a little less than two, which renders it necessary to fill up one of the moulds from the next ladle. Some casters are, however, particular either to take the ladle so full that it will make two full ingots, or to fill the ladles only so far as to make each ladle nearly fill one mould; this makes a light ingot. Most of the men, however, pour as full as they can without stopping, and pay no attention to the number of ingots. Some works make the ladles small, so as to have a uniformly heavy ingot, and prevent the contents of any ladle being poured into two moulds; but in most works the caster pours into the mould, which will be filled by the charge in the ladle, and will partially fill another. As soon as he ceases pouring a man with a fresh ladleful comes up behind him, and before the copper has a chance to cool at all, even on the surface, the mould is filled up.

The ingot moulds are placed together in batteries in a row over a trough filled with water. Eight ingot moulds usually make a battery. The water trough (Figs. 8 and 11, Plate II) into which the ingot falls, is called a bosh. When of wood it is made of the length and width desirable; when of sheet iron it is made the length of eight ingot moulds only, and of the width strictly necessary. The wooden boshes last but a short time although they are fastened with iron; the iron ones last indefinitely. The wooden boshes are strapped with iron on the bottom and are made of 2½-inch plank, 21 inches wide and 24 inches deep, and 20 feet 3½ inches on the inside. During the whole time of casting cold water flows into one end of the bosh and the excess flows out at the other. The water is turned off as soon as the casting is finished. The bosh is usually placed from ten to fifteen feet from the furnace. This distance is a matter of some importance; if it is less than ten feet the workmen are between the heat of the bosh and that of the furnace; if it is more than fifteen, the distance to travel is too great, and less work will be done. When the furnace is used for casting all kinds of shapes this distance must be arranged with the greatest care, for both the billet and plate moulds come between the furnace and the water bosh, so that the arrangement is sometimes made to have the billet moulds on one side and the water bosh in the front, with the plate moulds

in front of it. In some cases they are arranged on three sides, so that each is independent, in which case two at least of the distances are usually too long. The best disposition seems to be either to have the bosh in front and at such a distance that the plate moulds can be placed against it and the billet moulds on one side, or to make the boshes movable, so as to leave the whole front of the furnace free when ingots are not being cast. It is a mistake to arrange all these together as is sometimes done, as it incumbers the whole space in front of the furnace.

When twelve ingot moulds are full the men turn them over with a hook, turning them back two at a time. When a battery of eight has been turned over, the ingots are picked out of the water bosh with a pair of tongs and piled up in front of it. In some works the ingots are allowed to remain in the bosh until the whole charge has been ladled. This is not a good plan unless the bosh is very deep, as toward the last part of the casting it will be full of ingots. The man who tips the moulds uses at the commencement of the casting, when the ingot moulds are cold, a sponge to wipe out any water that may remain in the moulds. This is not necessary after a time, as the heat is sufficient to evaporate it. He is aided by another one who takes off with a rod any pieces of slag or other impurities that may float upon the top of the melted copper. This is easily done, as the impurities stick to the rod as soon as it is brought into contact with them. He also trims all the ingots when they are cold. The moulds, when turned over into the water, drop the copper ingots at once, when they are new, but after they have been used for some time they often require to be struck on the under-side, before they will deliver the ingot. At Hancock, where the work to be done is very large in amount, such a mould would be replaced at once. In some of the other works I have seen the tipper work at a mould five minutes to get the ingot out, and have seen moulds continuously used in which the ingot sticks every time, and only replaced when the ingot refuses to fall from the mould. In order to prevent too much jar, as the mould with the ingot turns with the top of the ingot next the face of the water, it is caught on the end of an iron rod and allowed to fall with but little shock. If it happens to strike in its fall the edge of the trough a yellow spot is produced on the ingot where it struck the wood. The moulds are left turned down until the ebullition of the water ceases to be very violent, and are then turned up again. They are then generally sufficiently hot to evaporate any water which may have been caught in them. This constant expansion and con-

traction of the copper moulds cracks them after a time. The contraction is, however, greater than the expansion, since the mould, which, at the commencement, will give an ingot of 18 pounds weight, will about the time it is used up, give an ingot of only 15 pounds weight. This contraction is also not equal in all parts of the mould, which is the reason why the old moulds fail to deliver the ingot.

The men who ladle have their legs covered with heavy hempen cloths, their right hands with a thick mitten of the same material well saturated with water. Notwithstanding their precautions these coverings often take fire from the heat. When the ladlers have poured the copper, they walk two or three steps, then throw the ladle down on the ground, let go with the right hand, and turn round the ladle holding it in the left hand, and walk to the furnace. The ladle is then thrown into the right hand, and the copper dipped. From 13,000 to 15,000 pounds of copper are made from each charge on Lake Superior.

At the end of the casting a coat of copper half an inch thick will be found in the inside of the ladle on the bottom. On the side towards the handle at the top of the ladle, it is about one and one-half inches thick, and projects over nearly an inch; a little is also attached to the outside. This is removed with a hammer, and is charged in the furnace with the ore. A ladle in constant use will last two or three months; it is then cut off from the handle and sold for old iron; the handles last indefinitely. The ladles are manufactured with a projection about six inches long on one side, which is welded to the old handle.

The man who does the tipping is provided with a hammer made wedge-shaped at one end and square at the other. The wedge end serves to remove the copper from the ladles and to trim the ingots; the square end, to hammer down any thin edges of copper on the sides of the ingots, and to catch them between the heels when they are hot, so that they can be handled. It is just large enough to go down between the two projections or heels, and is then wedged tight enough, by taking hold of the end of the hammer handle, to hold the ingot, and is easily separated from it by a slight inverse motion. If any burr occurs on the ingot, owing to the mould having been poured a little too full, it is either cut off with the wedge of the hammer or hammered down smooth with the square end. If any of the ingots show any slag or any defect, they are thrown to one side, and these, with the worn-out ingot moulds, go into the charge of ore. Only

very small pieces are ever thrown back into the furnace during the operation, as they would reduce the temperature of the copper.

The mould for the ingots is made of copper in a press. Fig. 5, Plate III, shows a drawing of one of the first ones ever made. It consists of a framework of iron, *a*, supported on a platform, *d*, through the two top supports of which an iron rod, *b*, passes into one of the ordinary copper ingots, which has been carefully filed up for the purpose. This is lowered by the lever, *e*, into an iron box, *f*, which is slotted together at diagonally opposite corners and held together by clamps. The under side of this box contains the slots for the V grooves. The box rests by its weight on a carefully planed iron plate, *d*, and is put into position every time a mould is to be made. The mould is filled two-thirds full of melted copper, and the ingot pressed into it until the copper is just even with its top surface, a few minutes only being required for the copper to set. As soon as the mould is sufficiently cool the lever, *e*, is raised, and the iron mould separated, and the ingot mould turned out, and another one cast. The mould thus comes from the frame with the dovetail ready to be shoved into the iron shoe, as shown in Figs. 9 and 10, Plate II, and ordinarily requires no fitting. These presses are now made with a screw cut on *b*, and a hand-wheel in the place of the lever *e*. At Hancock they generally make ten new ingot moulds to a charge. The cast-iron shoe into which the ingot mould is shoved (Figs. 9, 10, and 11, Plate II) is hinged on a rod (*c*, Figs. 8, 9, 10, and 11), so that as soon as the copper poured into the ingot mould is cool, it is turned over into the water, as shown in Fig. 11, and in this way forty moulds do the whole work of the establishment.

Two men can generally fill these forty moulds twice. The heat is so great that, after the second filling, they must be relieved. In very hot weather they cannot fill the forty moulds more than once, but, in very cold weather, they can sometimes do it four times. When eight moulds have been filled, the first mould is cool enough to tip into the water. This is attended to by one man, who does all the tipping. If, during the operation, the copper appears to be changing quality, a test is taken, which, on Lake Superior, is poured into an ingot, two inches square and twelve inches long, and this is tested for transverse strain. In the other works the ordinary spoon test is taken, and the condition of the furnace judged accordingly. Sometimes it is necessary to stop once or twice in the course of an operation to change the condition of a charge, which from want

of care in the management of the fireplace has run down in quality and must be brought back to tough pitch.

A great deal of importance is given by many to the color of the copper, and many qualities of it are distinguished in the market by their color. The temperature, at the time of casting, will not only affect the color, but will also change the appearance of the fracture. This is so well known, that most copper smelters ladle at as low a temperature as possible, in order to have the grain fine. The real and only test is not the color, but that the copper should be tough and malleable at all temperatures. Buyers, however, sometimes require copper to be of a certain color on the exterior, which, as is well known, does not give any positive indication of the quality of the copper. The coloring is only superficial, and, independently of the heat of the metal at the time of casting, can be given in several ways. Salt put into the water makes the copper dark red. This salt is simply put into the bath into which the copper tips. White-pine shavings put into the water make the copper yellow. The same effect is produced wherever the ingot, being thrown over, hits the wood of the water bosh. To form these colors, which are asked for specially, the ingot is tipped out upon a shovel, and then dropped into the water.

The shape of the ingots and the method of casting them are so peculiar that I have taken some pains to ascertain their history, as it is now here printed. I have collected the following data at different times from the statements of Henry Johns, of Pittsburgh.

In 1842 W. Thomas, a one-armed blacksmith, in the works of Pasco, Greenfield & Co., Swansea, Wales, impressed with the fact that the old methods of casting ingot copper were unnecessarily long and tedious, made a mould of cast iron supported on hinges, which he tipped into water. The contraction and expansion of these moulds broke them, and for this reason the process, which was at first thought to be a great improvement, was so expensive, that it was abandoned. In about a year it occurred to him that copper was the proper material of which to make the moulds. He placed these moulds on a frame, dove-tailed as they now are, and this method of casting in a water bosh was then universally adopted. His moulds, like the present form of English ingots (Fig. 16, Plate II) had, however, only one depression in the middle, and were longer, wider, and thinner than those cast in this country, but the weight was about the same. The two depressions in the ingots of copper which form the three heels, seem to have been introduced about 1848 in the works at Pittsburgh and Baltimore independently. Their object is to facili-

tate the breaking up of the ingot for the brass smelters, as the Lake Superior copper was extremely tough, while the English copper had hitherto been more brittle. This form of ingot was adopted on the Lake, and from there became the type form for all the works in the country. Only a few works make a lighter ingot than that used on the Lake. The machine for making the moulds (Fig. 5, Plate III) now used in the works of C. G. Hussey & Co., at Pittsburgh, is identical with that which Thomas first invented.

The copper at Hancock is cast at a higher temperature than is usual, to which the beautiful and uniform color of their ingots is mostly to be ascribed. The men have been so carefully trained, and are so very skilful, that they can produce great uniformity in the color. The care which is there taken to keep the quality of the heat the same, produces a copper containing less suboxide than any other, and hence it is much sought for when very pure copper is required. I have examined many samples, which did not contain more than from 0.03 to 0.05 per cent. of oxygen, and a few containing only 0.01 to 0.02, which is, so far as I know, not true of any other except Arizona copper, though any of the works could do it if they would take the trouble.

The ingots will average between sixteen and seventeen pounds in weight. They sometimes go as high as eighteen pounds, but generally keep within these limits. They are piled up in front of the casting trough, and packed in barrels, each barrel containing from seventy to seventy-five ingots, or 1250 pounds. The barrels are of oak; they are all made in the cooper shops of the Hancock works, which have a heavy stock of material expressly for this purpose. They are weighed with the heads and hoops on them. The weight of the barrel is marked in chalk on the outside. The barrel is placed upon a block of wood of less size than itself, and carefully packed with about the number of ingots it should have. It is then caught by an iron barrow or truck (Fig. 14, Plate II) which has two projecting prongs, which pass under the barrel and outside of the block. The open barrel filled with the ingots is then brought to the scales, on which a counterpoised iron block, of the same size and shape as the wooden one, is placed, upon which to deposit the barrel. The weigher tries with ingots of different weights to get the exact weight of 1250 pounds, and while this is done by changing the ingots in the barrel for lighter or heavier ones, the head and hoops of the barrel remain on the platform of the scales. When the weight is correct, they are placed on the barrel, the truck run under the iron barrel-rest on the platform of the scales, and the barrel carried off

and placed upon the ground near the place where it was packed. It is then headed and rolled again to the scales, where the weight previously chalked is checked, and, if found to be correct, it is rolled to the dock and shipped. Whenever the work of packing the barrels is finished the men go home, except those who watch the furnace during the night. As this may be as early as 3 P.M., these positions about the furnace are on Lake Superior considered very desirable. They are never given except to their best men, who look upon it as a post of honor, from which some of them have risen to high position in the works. They consider themselves as a *corps d'élite*, and not only do excellent work, better on the whole than is done elsewhere, but remain at the works permanently, much to the benefit both of the company and of themselves.

The greatest care is taken to keep the products of each mining company separate. Every company has its own ingot moulds with its name in the bottom, so that each of the ingots has the name of the mine from which the copper comes cast on it.

The ladles, rabbles, and all other iron tools have copper on them, which cannot be separated with a hammer; this is melted off and sold for half a cent a pound.

It is not easy to calculate the cost of the operation of smelting. The works at Hancock naturally control the price, as all the other works in the United States put together would not be capable of turning out at the present time much more refined copper than they do. They are naturally very uncommunicative about their business transactions, and the probable cost can only be estimated. That they make a very large profit, the dividends which they declare make certain; what that profit is can only be known approximately. The work of smelting is done at a fixed price per ton of ore or mineral, no matter whether this is No. 5 mineral, which only contains 35 to 40 per cent., or No. 1, which contains on an average 90 per cent., or masses, which are nearly pure copper. Within three or four years this price was $18 per ton of ore and $15 per ton of slag. Latterly, it has been reduced to $17 for the ore and $12.50 for the slag at Hancock, and $15 for the ore and $10 for the slag at Detroit. It is therefore for the interest of the mines to send to the smelting works the richest possible products. At Hancock all the coal, flux and other material is brought to the works as return freight in vessels that would otherwise come back from the East empty. Each furnace uses four tons of coal in twenty-four hours, which costs $4.40 per ton. For labor

there are two men for the first shift of twelve hours, and six during the second shift, which lasts until they are through. The furnaceman is paid $3.50, two helpers $3 each, and the other $2.50 per day. There will thus be $19 a day expense for labor.

Dr. Kupelwieser* calculates the cost as follows:

	Per ton of ore.	Per ton of copper.
Labor at the furnace, ...	$2 40	$2 93
Other labor, ...	1 00	1 23
Four tons of coal @ $4.40, . . .	2 20	2 70
Cost of direction, ...	3 00	3 70
	$8 60	$10 56

This shows a very handsome profit for the works. This estimate seems to be a low one, but, however near the truth it may be, it is certain that the very large amount smelted, and the peculiar facilities for freight, make it possible to treat the ore for a comparatively small sum.

The second part of the operation consists of the fusion of the rich scorias in the cupola furnaces, which gives as a result poor scorias, which are thrown away, and a black copper containing a great deal of iron. This operation is conducted in different ways at different works. On the Lake the slags are simply smelted in the cupola. At Pittsburgh they are first submitted to a treatment in a reverberatory furnace, and the rich slags from this treatment go to the cupola. The cupola furnaces which are used are also quite dissimilar. The treatment on the Lake will be given first, and afterwards that at Pittsburgh, in so far as it differs from it.

At Hancock and Detroit most of the slag, except what shows metallic copper, which is skimmed during the night, goes to the cupolas. All that is skimmed during the poling goes back into the refining furnaces. The slag which goes to the cupolas will be about 35 per cent. of the charge in the reverberatory furnace. The scorias from the treatment of the copper from each mine are always kept separate and treated separately. They are made into heaps or put into the bins marked with the name of the works, and left until a quantity sufficient for a ten hours' run in one of the three cupolas has accumulated. The scorias, as the analyses show, contain metallic copper in grains, oxide of copper, oxide of iron, alumina, lime, and magnesia. The object of the fusion is to melt and collect all the copper which is in grains, to reduce the oxide of copper, and to get another

* Bericht uber der Weltaustellung in Philadelphia, 1876; Vienna, 1877, p. 27.

set of scorias poor enough to be thrown away; to accomplish this some iron must be reduced, but in order to make the quantity as small as possible, the oxide of iron is left to take all the silica it can get from the bricks of the furnace. The slag generally contains from 5 to 12 per cent. of copper, some of which is in the shape of grains of metallic copper, though the analyses of the slags (p. 698) show much lower than this. The average of the working of many hundreds of tons is given, however, at the works, as between these two amounts, though I have frequently seen very large pieces of suboxide of copper, and have analyzed a number which contained over 40 per cent. The furnace which is used on the Lake is a modified Mackenzie's cupola. This furnace was originally invented for the fusion of cast iron, but has been so modified that it is now the best furnace in use for the treatment of copper slags. Its peculiarities are the water bosh, the tuyere, which is in the shape of an opening five-eighths of an inch wide all round the furnace just below the water bosh, and the crucible at the bottom for holding the copper from a large quantity of slag until it shall accumulate in sufficient quantities to make it desirable to cast it.

The cupola (Plate IV) has on the outside a mantle of iron lined with a single thickness of fire-brick with a drop bottom, and is 32 feet high to the top of the chimney. It is elliptical in form, and rests on the bottom, on a cast-iron ring, which is supported on four cast-iron columns 4 feet 6 inches high. Immediately over the bed-plate is a chamber (*i*, Figs. 1 and 3), 22 inches deep, with a major axis of seven feet, and a minor of 4 feet 9 inches, which serves as a crucible in which the copper collects. Immediately above this is the slag-chamber (*y*, Figs. 1 and 3), which is 12 inches deep up to the tuyeres. The slag discharge (*j*, Figs. 1, 2 and 3), is in this chamber, and consists of an opening which is horizontal through the lining of the furnace, and then rises at a sharp angle as shown at *j* (Fig. 3). To hold these spout bricks a nose is riveted upon the mantel. When the furnace is at work the spout is covered temporarily with bricks, so as to make a downward opening on the outside, through which the slag flows continuously while the furnace is in blast. Next the bottom there are two openings (*p*, Figs. 3 and 4), which are used to let the flame through when the bottom of the furnace is being heated.

The boshes are made of cast iron, and consist of a water-chamber (*o*, Figs. 1 and 3), going round the whole furnace. This is made in sections and fitted together so as to be water-tight. The inner and lower sides

are five-eighths of an inch thick, the upper and outer ones are half an inch. It thus forms a water bosh, which is infusible at any temperature which is likely to occur in the furnace. Its position is determined by the height at which the bricks melt, and its upper surface is put there; it is 22 inches high. Water constantly flows through it, supplied by a three-quarter inch pipe (*d*, Figs. 2, and 3), and is discharged at *e* (Figs. 1, 2 and 3). Around the water bosh is an annular chamber (*g*, Figs. 1, 2 and 3), into which the air passes from a pipe (*f*, Fig. 1), which enters the air-box *x*, bolted upon the mantel of the furnace and communicates with the air-chamber (*g*, Figs. 1, 2, and 3), which surrounds the walls. The air enters the furnace through an annular opening (*h*, Figs. 1 and 3), five-eighths of an inch wide, which serves as tuyeres, and thus distributes the blast evenly in every direction. The bosh slants slightly, and from its top the furnace rises vertically 5 feet 8 inches, with a major axis of 7 feet 9 inches, and a minor axis of 5 feet 6 inches to the bottom of the charging door (Fig. 1) which is 2 feet square. From here it slants until at 8 feet 6 inches it has a diameter of 4 feet, at which point it terminates in a chimney 9 feet high.

The cupola house is 65 feet long, and the part of the upper story devoted to the top house is 20 feet wide. At the end towards the refinery there is a space 7 feet 6 inches wide for an inclined plane made of railroad rails. At right angles to it, at the top, is a railroad 42 inches wide, which serves the cupolas, and on which a truck with very small wheels (Fig. 10, Plate IV) runs through a passage which is 4 feet 6 inches wide. This truck receives the loaded car as it arrives at the top of the incline, and transfers the wagon in a direction at right angles to the inclined plane without turning. Each cupola has a bin 15 feet long by 15 feet wide, and 4 feet below the level of the track in front of it. The cupola projects half its diameter in the centre of one side of this space. On each side of the rim is a rectangular projection of the height of the top of the small truck, which is 3 feet 6 inches wide, and 6 feet 6 inches long, which projects equally into each bin. The cupolas are charged with slag, anthracite, and limestone, the latter being crushed in a Blake's crusher. It is brought from Kelly's Island, in Lake Erie, and costs 60 cents a ton for transportation. The anthracite comes from Sugarloaf Mountain, does not decrepitate in the furnace, and is of good quality. The slag, anthracite, and limestone are brought to the top of the cupolas on the inclined plane in a wagon which swings on a pivot.

(Fig. 10), where it is transferred to the little truck, and is rolled to the place where it is to be discharged. The wagon without the truck is rolled upon the platform behind the cupola, turned in the necessary direction, and dumped on either side, so that the supply for two adjoining bins comes from the same platform. The flux is discharged to the right, and the slag to the left hand of the charge. The coal is discharged at the end of the platform directly in front, and against the furnace, but away from the charging door. The rest of this story of the charging-house is occupied with floors for the crushing and sorting of old bricks to be used for the manufacture of grouting and bricks, and other accessories to the cupola. The charging door is 16 inches above the level of the floor, so that the charge is made with great ease.

When the cupola is to be put into blast, it is always heated up the night before. To do this, water is run into the water bosh, the coke charged, the charging door closed, and it is allowed to burn all night to get up the requisite heat, and the regular charge is made in the morning. From 500 to 600 pounds of coke are used for heating. The regular charge consists at first of 60 shovelfuls of coal, 100 of slag, and 40 of lime; after this the charge is 40 shovelfuls of coal, 100 of slag, and 40 of lime; or for each ton of slag 700 shovelfuls of coal, and 800 to 900 of lime. If the charge of slag is 20 tons, this will make 7 tons of coal and 8 or 9 tons of lime. The usual consumption of coal is between 6 and 7 tons. Besides the regular charge, scraps of copper and refuse to the amount of one-half a ton, are put in. The blast used is produced by a No. 5½ Baker's rotary pressure blower. The pressure is 17 inches of water.

Each furnace treats 18 to 20 tons of slag in about ten hours. One man does all the charging for one furnace. Below there are two men, one of whom breaks up the slag, and one takes charge of the copper. After a ten hours' run, the furnace must be repaired before it is used again. There is so much iron in the slag that the bricks in the lower part of the cupola are cut into about three inches, so that it would only be possible for the furnace to run a few hours longer than it does. In making ordinary repairs, the bricks are plastered over with mortar. Every three months all the bricks below the water-back must be taken out. Above this point, except replacing a few bricks in front, the furnaces last five years without repairs. About ten thousand fire-brick are required per year for the repairs to the three furnaces. When a cupola has been lined throughout, it must be allowed to stand a few days to get rid of as

much moisture as possible. It is then carefully dried before being heated up for the charge. The bottom of the crucible is made of two cast-iron doors (*r*, Figs. 1, 2, and 5, Plate IV), which are hinged to the sides of the cast-iron bottom-plate, one of which projects a little over the other. They are held up during the operation by a wooden post (*z*, Fig. 1), which is taken away when any repairs are to be made. The doors then fall and leave the whole shaft accessible from the bottom. Occasionally the doors stick; they are then pried down with tools. Sometimes the doors open, but the loupe in the bottom does not come out; it must then be worked out with one or the other of the two tools (*v* and *w*, Figs. 7 and 8, Plate IV, to support which a rest *u* is used, which is held in flanges *t*, cast in the iron columns *q*. The hearth of the crucible is put in from the inside by means of a ladder. It consists of river-sand, closely beaten down, and is from 5 to 6 inches in thickness. This bottom is taken out after each operation, as it is very rich in copper, and goes back into the cupola furnace. It is charged with scrap rich in iron, and is very easily melted. It was formerly used in the charge in the reverberatory furnace. The water bosh requires 25 gallons of water per minute, and is so regulated that the water running out of it is very near the boiling-point. Advantage is taken of this discharge water in winter to keep the pipes from freezing. For this purpose the supply-pipe, which is one and a quarter inches in diameter, is run through the centre of an iron pipe three inches in diameter. The hot water from the water bosh discharges into one end of this pipe in the winter and is discharged at the other, thus keeping the supply from freezing. When the furnace in the winter-time is to be out of blast, the water in the water bosh and the cold-water supply-pipe are first emptied, and then the hot-water jacket.

The men at the furnace are, one charger, one slag man, one copper man, four men at the cars, two men with the teams, and one at the Blake's crusher, who is occupied part of the time in crushing old fire-brick for the manufacture of the brick and grouting used in the repair of the furnaces. The slag flows continuously, and discharges from the slag spout (*j*, Figs. 1, 2 and 3) into a basin (*n*) made of sheet iron and filled with sand (Figs. 3 and 4), which is placed on a heap of old slag, so as to leave the top just under the capitals of the iron columns supporting the cupola. There are two of these slag basins, but only one of them is used at a time. They are oval in shape with the ends cut off, and are 6 feet 6 inches long, 3 feet 6 inches wide in the middle, and 2 feet 9 inches at the ends. The slag flows slow-

through this basin, where any copper, mechanically carried off, will be collected, and then runs over the opposite edge to the waste pile. Sometimes a slag wagon (Fig. 11) is used in the place of the fixed receiver. This wagon is made of iron, and is rectangular in shape; it is 4 feet 10 inches long, 2 feet wide, and 17 inches high. It has a round slag spout, 6 inches wide and 3 inches deep, bolted to it. The bottom of the wagon is 26 inches from the ground. The slag spout of the furnace is covered with brick down to the slag receiver. The slag flowing from the spout soon cools on the surface in the slag basin, but remains liquid underneath, and in order to keep it so, pieces of bituminous coal, which are kept burning, are placed at the spout and on the overflow from the basin. The slag is so very long that it flows frequently 10 or 15 feet under a cold crust, the liquid occasionally breaking out and coming to the surface. These slags, which are much more fusible than they were before the cupola treatment, owing to the addition of the flux, should be very poor. I was not allowed to take any samples for analysis during my different visits to the two works, nor have I been able to obtain any since 1869; but they are said to contain as low as 0.25 per cent. If they contain more than 0.75 per cent., they are re-treated. From 29 to 30 tons of slag are made from each operation. The slags are allowed to accumulate in front of the cupola, and are removed in carts and used to make ground, for which purpose they are very valuable.

The copper in the slags, which is in the state of oxide, is reduced by the action of the gases in the furnace; the copper in grains settles, as soon as the slag is melted, to the bottom of the crucible. It is so deep that there is little fear of any amount of the copper being carried off in the slag as grains, the construction of the slag-discharge being such as to prevent it as far as possible. If any should flow off it will be caught in the sump through which the slag flows. There is generally from thirty to one hundred pounds of it caught here. Sometimes a cake thirteen inches in diameter, and two to three inches thick is made; sometimes a flatter cake of much larger size and weight, depending on the fluidity of the slag.

At the close of the day when the entire charge has run through, the copper will be ready to cast. The casting-spout (*l*, Figs. 3 and 4), is made of iron, bolted upon the mantel of the furnace. It is filled with refractory material, so that as it enters the furnace it is 1 inch in diameter, but 4 inches wide at the other end. It is 9 inches long and 2½ inches above the bottom door, but on a level with the sand

bottom. The casting-bed (*m*, Fig. 4), is just below the spout. It is made of cast iron, is 5 feet 9 inches by 2 feet 6 inches wide and 20 inches at the ends. The middle of the long side is placed under the spout. Just before the casting is to take place an iron hook is placed in the centre of this bed, in order to allow of the black copper being lifted from it. The tap-hole is then opened with pointed iron bars and the copper cast in a bed of loam. As soon as it is cool it is raised by means of an overhead crane (Figs. 12 and 13), running on rails, and charged on a wagon ready to go to the refining furnace. From a ten hours' run 1800 to 2400 pounds of pig copper are produced, which goes to the refining furnace, and is treated with the ore.

At Pittsburgh the slags when cool are picked and separated into rich or foul slags, and poor slags. The foul slags, which are produced after the complete fusion of the copper, go immediately to treatment in the reverberatory furnace, and the poor, which are produced during the melting, to the cupola. The reverberatory slag furnace is of the same size as the ore furnace, but the hearth slopes to the side instead of to the end. On the sides of the fireplace there are openings left to admit all the air required for the oxidation of the blister copper.

The slags are allowed to accumulate until the supply of ore ceases, which it does in Pittsburgh in the winter-time, and are then all worked at one time. If there were more furnaces there they would be smelted continuously. The product resulting from this operation is a pig copper, which is treated as an ore with the ores. A very foul slag results, which will contain as high as 10 or 12 per cent. of copper, which is put back as a flux in the same furnace. To treat the slag three tons are charged at a time. It takes seven to eight hours to melt this amount. Another three tons are put in, and so on, and this is continued for two or three days. When enough blister copper has accumulated in the bottom of the furnace to cast, it is run out into three "pairs of pigs," by which three pigs are meant. Every two hours the slag is run off the top of the charge. This slag contains 4 to 5 per cent. of copper, and goes to the cupola furnace. The quantity of fuel required is three tons of coal for nine tons of slag, the ton being counted as 2000 pounds. Twelve per cent. of this is 240 pounds of black copper, so that it must be allowed to accumulate in the furnace for a considerable length of time to make three to five tons when it is cast. If, when the slags are withdrawn, the melted copper is not sufficiently blistered, the doors are opened,

and it is allowed to oxidize. This furnace requires one melter and one helper in twenty-four hours.

The clean slag from the copper smelting and all that comes from the reverberatory furnace go to the cupola. The following is a sample of the slags sent to the cupola at Pittsburgh:

MECHANICAL ANALYSIS.

Metallic copper,	0.22
Siftings,	99.78
	100 00

ANALYSIS OF THE SIFTINGS.

Protoxide of iron,	10.53
Copper,	5.44
Oxygen with copper,	1.37
Oxide of zinc,	0.43
Oxide of nickel,	0.08
Oxide of manganese,	0.12
Alumina,	15.86
Lime,	11.81
Magnesia,	2.57
Silica,	49.83
	97.54

The cupola furnace is of the ordinary kind, and stands on iron pillars 30 inches from the ground. From the platform above the pillars it is 10 feet high. It is 3 feet in diameter throughout. The three tuyeres are on the same level, and are 18 inches above the bottom of the furnace. These tuyeres are not equally spaced around the furnaces; two are at 18 inches, and the third at 26 inches from these, so as to prevent a counter action of the blast. The space below the tuyeres forms the crucible. There is no crucible proper, as in the furnaces at Hancock. The bottom is closed with iron doors, and is held in place, when the furnace is in blast, by an iron bar. The hearth proper on the top of these doors is made of about a foot of sand well-beaten, with an inclination from every direction towards the tap-hole. The casting-beds are cast-iron boxes 6 feet long and 3 feet deep placed a little below the level of the tap-holes. The sides of the box are made of two pieces bolted together by flanges cast on them; the ends are bolted upon the side. The slag spout for the overflow is cast on the end piece. There are two of these beds, on opposite sides of the furnace. They are used on alternate days, so as to give an opportunity for repairs. They are lined with one thickness of brick and have a bottom of sand. The pressure of the blast is 12 inches of water.

is very interesting to watch the variation in the quantity of oxygen as well as in the amounts of the other impurities which do not remain constant during the same operation, showing beyond a doubt that as a whole the bath of copper is not homogeneous in composition.

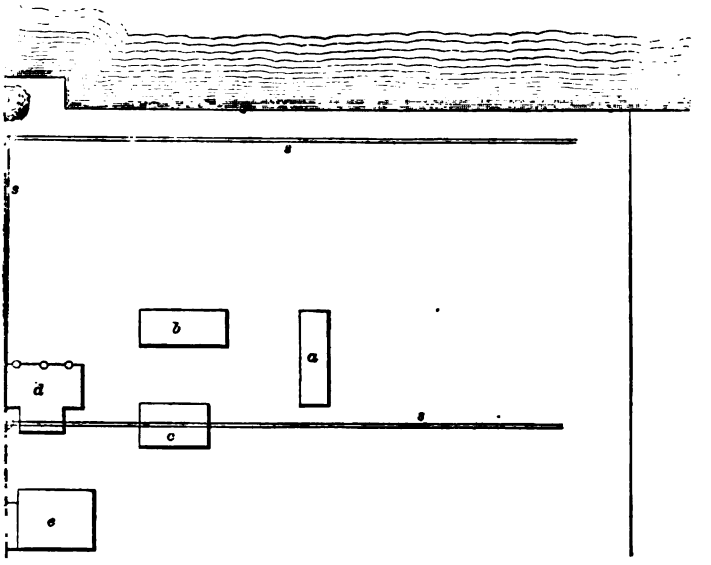
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11
Copper.....	99.92	99.90	99.89	99.87	99.83	99.82	99.81	99.80	99.740	99.55	99.5
Iron.....	.....	.....	0.005	.....	.....	.....	0.008	.....	0.011	0.03	0.0
Nickel.....	.....	0.002	0.003	0.003	0.003	0.09	.....	0.02	.....	.....	.....
Cobalt.....	.....	.....	.....	.....	trace	.....	trace	.....	.....	trace	.....
Lead.....	.....	.....	.....	.....	.....	.....	.....	.....	0.012	.....	.....
Silver.....	0.08	0.03	0.03	0.02	0.03	0 06	0.03	0.04	0.024	0.07	0.0
Oxygen.....	0.28	0.28	0.19	0.27	0.22	0.28	0.30	0.28	0.014	0.37	0.3
	100.23	100.212	100.118	100.163	100.083	100.25	100.148	100.14	99.801	100.02	99.8

These eleven analyses show that the samples are of a higher quality than any of those before published. They have been selected as examples of what can be done. The more common determinations of copper are 99.78, 99.72, 99.73, 99.58, 99.53. The amount of lead varies from nothing to 0.044. Twelve samples gave the following results: No. 1, 0.016; No. 2, 0.044; No. 3, 0.012, No. 4, 0.025; No. 5, .014; No. 6, .014; No. 7, .005; No. 8, .033; No. 9, .011; No. 10, .013; No. 11, .018; No. 12, .016. The silver varies from 0.02 up to 0.12 per cent. It is not evenly distributed through the mass, as the eleven samples taken from the same charge at intervals of half an hour, whose analyses are given above, show differences of several ounces. The following determinations, which were made at intervals of fifteen minutes, also indicate the same want of homogeneity. They are arranged in the order in which the samples were taken:

0.013 0.013 0.004 0 032 0.010 0.012

The amount of iron is exceedingly variable; many coppers do not contain it at all. The limits that I have found are 0.01 to 0.04 per cent. Nickel and cobalt vary very much. They are often entirely absent. The quantity of cobalt even when present is generally too small to be weighed; it varies from 0.002 to 0.08 per cent. Zinc can almost invariably be found, but is generally in too small quantities to be determined. Very often it can only be detected by the spectroscope. A series of determinations in which the cobalt, nickel and zinc were determined together, the quantity of cobalt and zinc having been found too small to separate, gave the following results: 0.069, 0.017, 0.021, 0.052, 0.002, 0.063, 0.006, 0.053, 0.07. Four other determinations gave 0.10 each, two 0.11 each, and four 0.12 each.

The copper which is made from ores found in Arizona seems



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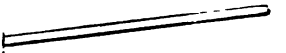

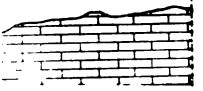

Fig.13

Fig.15

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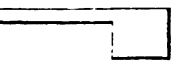

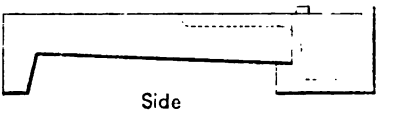

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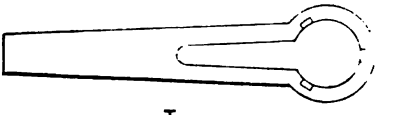

Top

Pittsburgh tough pitch test mould

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SCALE

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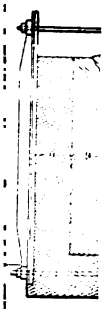

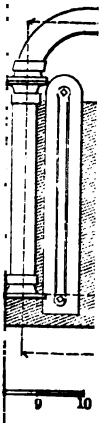

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NACE

likely to be, when carefully refined, even superior to Lake copper. I have had no opportunity to follow the refining of the pig as closely as I have done the refining of Lake copper, but examinations that I have made of some of the copper produced show that it is of exceptional purity. The following are the results of two analyses:

Copper,	99.990	99.990
Iron,	0.021	0.014
Zinc,	trace	trace
Silver,	0.008	0.008*
	100.019	100.012

No other metals were discovered, although careful search was made for them on large quantities of the copper. The very small amount of silver in the coppers of this district is very remarkable.

In examining recently some copper made from Colorado ores, which was so cold-short that cracks nearly half an inch deep were shown in the copper after its second passage in the rolls, I discovered a very appreciable percentage of tellurium. The copper could only be used for making a brass of very poor quality. This is the first time, so far as I know, that this metal has ever been found in refined copper. I hope to be able to make a careful examination of this material.

What is most remarkable about all the American coppers, as well the Lake coppers as those from some of the Eastern sulphurous ores, is the entire absence of arsenic, antimony and bismuth, which would indicate that the copper is of very high quality.

The copper made from impure Western sulphurous ores is not so good, as the analysis given below shows.

Copper,	99 650
Oxygen,	none
Carbon,	none
Sulphur,	none
Arsenic,	0.088
Antimony,	0.035
Lead,	0.044
Silver,	0 066
	99.883

Other sulphurous ores free from arsenic and antimony give copper equally pure, as the analyses of the copper from Ore Knob show.

* This amounts to but little over two dollars to the ton.

Copper,	99.80
Oxygen,	0.39
Carbon,	none
Sulphur,	none
Arsenic,	none
Antimony,	none
Lead,	0.01
Silver,	0.05
	100.25

There is every reason to believe that if the pure ores of the great Appalachian Range were carefully worked, they would yield a quality of copper in every respect equal to Lake, except perhaps, on account of the cobalt and nickel, for the single quality of electrical conductivity, and even here they might sometimes compete.

The tensile strength of Lake copper as shown by several tests made on the U. S. testing machine, is 30,790 pounds to the square inch.

In conclusion I beg to express my thanks to Mr. J. Park, Jr., and to Dr. C. G. Hussey, of Pittsburgh, for drawings, and for information relating to the history of smelting; and to Mr. H. Johns, of the Soho Works, who has given me many points of historical interest, has taken for me all the samples for analysis for which I have asked, and has kept some of the charges in the furnace waiting for me to study them.

*RELATIONS OF THE GRAPHITE DEPOSITS OF CHESTER COUNTY, PA., TO THE GEOLOGY OF THE ROCKS CONTAINING THEM.**

BY PROFESSOR PERSIFOR FRAZER, PHILADELPHIA.

AMONG the geological problems with which the present Pennsylvania Geological Survey has had to deal is the relative age of a series of strata passing around and through the city of Philadelphia, Bucks, Chester, and Delaware counties. Rogers includes all these rocks in his hypozoic series, and every student, so far as the writer knows, with one exception, has assigned to them a position beneath the Potsdam sandstone, or "Primal" of that eminent and gifted geologist.

So far as regards the small portions of this belt, to which it is the intention of the present paper to draw attention, even the one geolo-

* Read at the Lake Superior Meeting, August, 1880.

gist, whose views of other portions of the belt have been alluded to above as being different from the rest (Mr. Charles Hall), is in accord with all others as to its being below the horizon of the Potsdam. The rocks are of very different texture, and change rapidly in character within small distances within the area alluded to; and this is not the only lithological difficulty which they present, for the character of one of the rocks itself is oftentimes so ambiguous as to lead the observer to doubt whether it be a true conglomerate, or breccia, or a crystalline rock. Similar difficulties in determining the true character of rocks are not infrequently met with by geologists; and a similar case has been alluded to by the writer in his report on the geology of Adams and York counties, Pennsylvania.

Passing up the eastern feeder of the north branch of the Brandywine, north of Downingtown, the rocks appear to pass from quartzite to hornblendic gneiss, but at what precise point is not clear. Almost every imaginable variety of transition rock is found.

Proceeding in like manner along the road which divides both townships in opening a way from Lionville to Stephen Griffith's store, after leaving the quartzite, which is with comparative certainty to be ascribed to Potsdam age, south of Lionville, we find about that town this weathered feldspathic rock, taken at different times for a conglomerate with bluish quartz and a matrix of feldspar, and again for an original crystallized rock. Then follows a stretch of road on which quartz débris principally predominates without admitting of any certain surmise as to its original condition; then more of the feldspathic rock to the town of Windsor and beyond it, when, after an interval of loose sand, the feldspathic granite continues to the northern edge of the county, interrupted only once by the occurrence of fragments—possibly transported—of quartz or sandstone.

Near the town of Windsor, and some quarter of a mile south of the Phœnixville and Pickering Valley Railroad, is a mine opened for graphite, and now owned by the Pennsylvania Graphite Company of Reading. This company leased 500 to 600 acres of the estate of John Todd, deceased; and one mine adjoining the mill has been running continuously, ever since the graphite was discovered lying in flakes on the ground, by Mr. Berrett and Dr. Thomas Brown. This belt of feldspathic rock with bluish or amethystine quartz, containing graphite, has been traced all the way to Phœnixville, and in the same course, but opposite direction, to the Brandywine; but its occurrence in quantity is confined to a width of a few hundred yards, though its existence can be proved on almost any

farm in the district. Another belt, nearly parallel with this one, runs through Pughtown, but is said not to be as rich as this one, by those interested in the latter.

The mine is opened about 60 feet in depth by open stope along 500 feet of the outcrop. The portion of the rock sufficiently permeated by graphite to pay for excavation was 12 to 15 feet from wall to wall. The dip of the underhand stope is south 15° E.–30°. At the western extremity of the gangway the rock is a decomposed gneissoid rock containing several large horses of a whitish rock, similar in character to the foot.

From 50 to 80 car loads were sent up per day (August 12th, 1880), each car containing about half a ton. The ore contains perhaps 4 per cent. graphite. The engine is 30 horse-power, working pumps by flat rods, making five 3-foot strokes a minute, and throwing 3 or 4 gallons to the stroke. Seven hours' pumping keeps the mine dry for twenty-four hours. Twenty-eight men were employed in the mill and twelve in the mine; five miners, at $1.25, and seven laborers, at $1.10 per day. The engine runs the pumps during the night and the machinery during the day. The car drivers work on contract for six cents a car.

The rock from the mines is crushed and passed into an agitator, where it is jigged, the lumps having been broken. Two men manage the washers on night and day shifts at $1.10. Two men and two boys are employed at the mill. From the jig or agitator the ore is carried to the furnace, where it is heated and separated into four parts. The first ("No. 2") is gravel of the size of a pea and quite free from graphite.

The next is the cleanest part of the first separation, but still contains 33 per cent. to 50 per cent. impurity ("No. 3").

The next is the fine dust, containing a large proportion (50 per cent. ?) of graphite, but which is thrown away ("No. 4").

Altogether in mill and separator about four tons of anthracite (Schuylkill coal) at $5 are used per day.

The first grade from the separator is brought to the mill, where it is ground in Cornish rolls, falls into a vat, and is carried by an elevating belt up to the loft, where it is bolted through bolting cloth, and is conducted thence to the kiln. The bolting cloth here used is a wire screen, 60 meshes to the inch. The operations are somewhat in order as follows:

I. The product of the separator is crushed in iron rolls, and is carried to the top of the building, where it is bolted.

II. It is then dried in kilns. (The fine is buddled, and is then treated along with the rest by process III.)

III. The material is bolted through two bolting cloths No. 12, like grist-mill cloths, and separated into 1, 2, and 3 grades. No. 3 is the finest. This latter grade, ground in a buhr and bolted again, produces the finished product. The quality of this article appears to be excellent.

The chief interest here, however, of this graphite deposit is found in the light that it sheds on the probable age of the rocks in which it occurs. In the first place, the occurrence of graphite in such large quantities would lead us to ascribe the rocks which contain it to either the Laurentian or the Huronian period. It is true that graphite is met with in the Lower Silurian,* and it has been thought to have been recognized in the Carboniferous, but not in the form in which we here view it. From other analogies Dr. Hunt, in the essay on the *Geognosy of the Appalachian and the Origin of Crystalline Rocks*, is induced to ascribe to this region the age of the Green Mountain series, and the occurrence in these rocks of graphite would tend to increase this resemblance.

It will naturally occur to one that if the original graphitic Laurentian or Huronian rocks had been torn up and made over that their constituents would also exist in the newly-formed rocks. The manner in which the graphite is distributed forbids this supposition. For being of much lower specific gravity than the matrix in which it is imbedded, a disintegration of the rock would lead to the aggregation of the graphite into the same horizon or bed, whereas it is disseminated entirely through the rocks in which it occurs.

It would seem, therefore, to tend to show that the age of these rocks was Laurentian or lower Huronian.

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* See T. S. Hunt, *Chemical and Geological Essays.*

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